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Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002–20

January 2022

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

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NOAA FISHERIES

Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002–20

Jason E. Jannot, Kate E. Richerson, Kayleigh A. Somers, Vanessa J. Tuttle, Christa M. Colway, and Jon T. McVeigh

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

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PACIFIC HALIBUT BYCATCH 2002-2020

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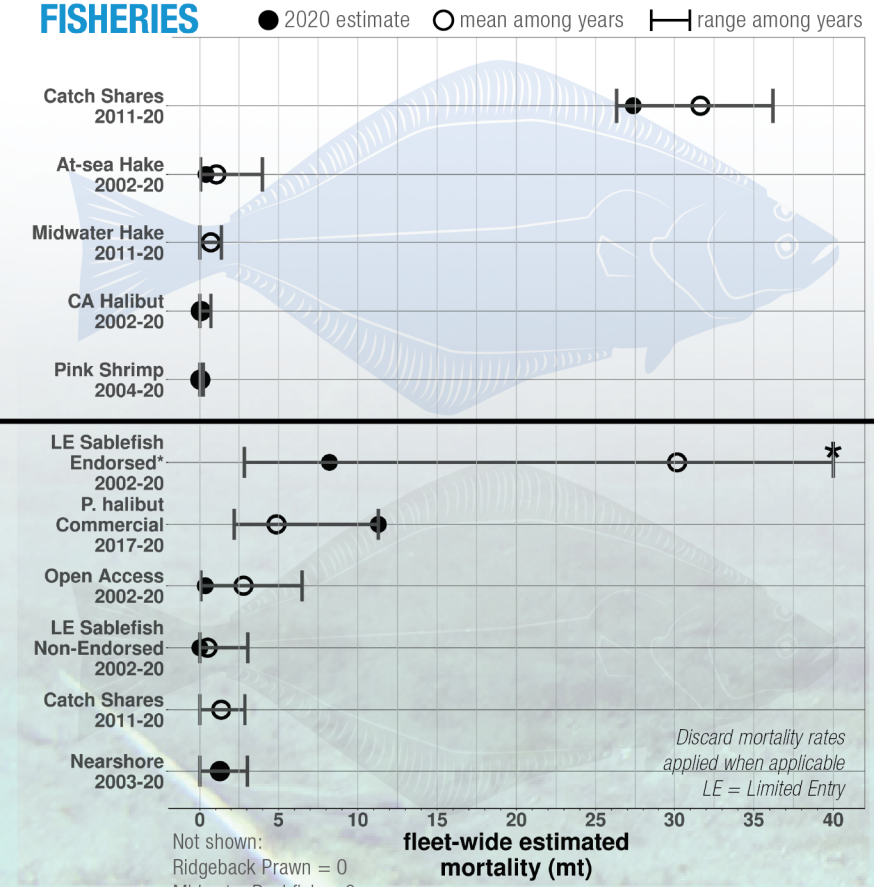
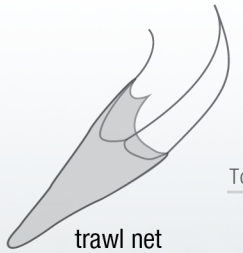
https://go.usa.gov/xfG68

NOAA FISHERIES

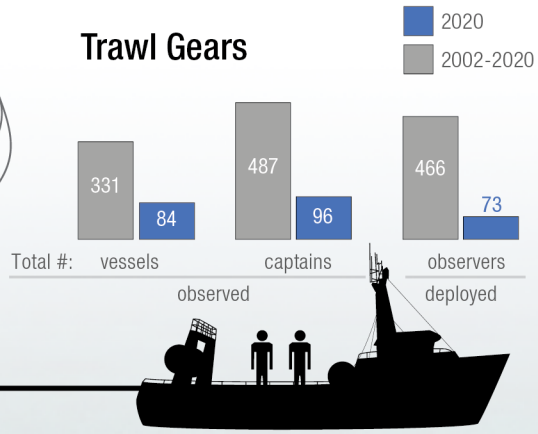


Not shown:
Ridgeback Prawn = 0
Midwater Rockfish = 0
Catch Shares Fixed Gear and Midwater Hake 2020 confidential

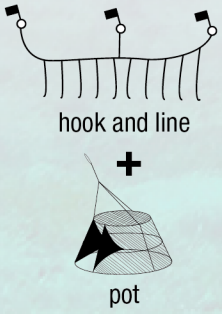
2020 Catch Shares IBQ
Allocation (mt) : 66.34
Attainment (mt): 29.15



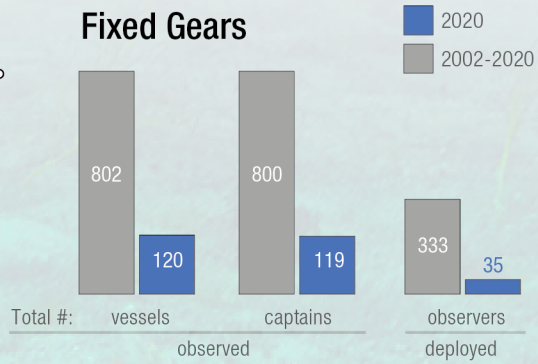
Trawl Gears



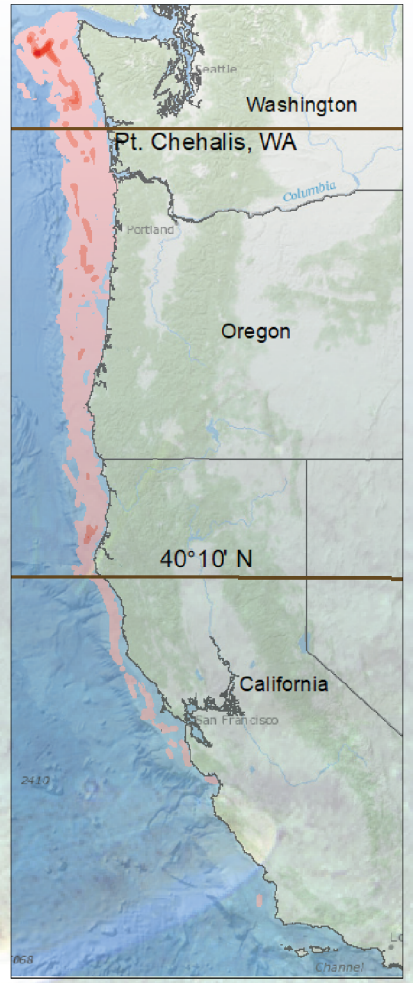
*maximum = 107.3 mt



Fixed Gears



Pacific Halibut Bycatch
Observed 2002-2020

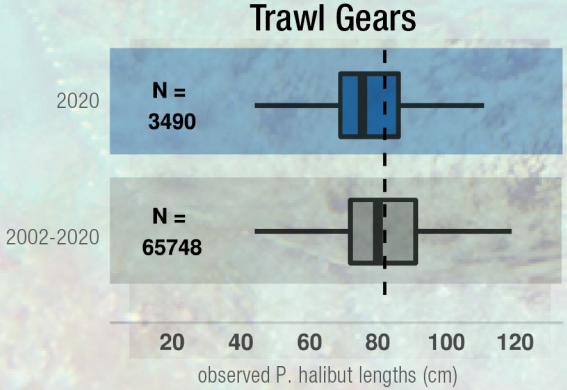


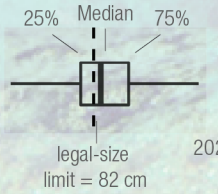
Map by K. Somers

Pacific Halibut Catch (mt / sq km)
0.07 - 0.82
0.83 - 2.53
2.54 - 6.1
6.11 - 12.12
12.13 - 18.96

N
0 75 150 300 N Miles

Trawl Gears





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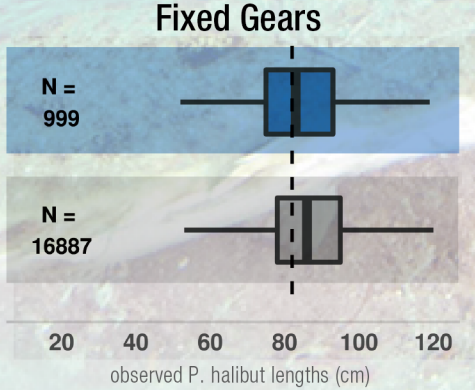
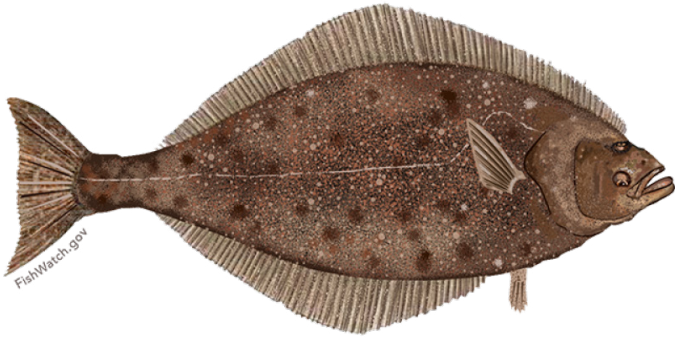


Plain Language Summary

Background

Pacific halibut are large flatfish that live off the west coast of North America, from Alaska to Central California. Both sport and commercial fishers target them for their size (they can weigh up to 500 pounds) and flavor. Halibut are sustainably managed by both the United States and Canada through the International Pacific Halibut Commission, which sets annual limits on how many halibut can be caught by each country.



The Commission needs to know how many Pacific halibut are caught each year, both when targeted in the directed Pacific halibut fishery, and when caught while targeting other species ("incidentally"). At the Northwest Fisheries Science Center's observer program, we track how many halibut are incidentally caught each year. Incidentally caught fish, or "bycatch," are usually discarded over the sides of fishing vessels while still at sea—so they are also called "discards."

We collect data by direct observation, electronic monitoring, and from fish sales information. We estimate total Pacific halibut bycatch each year, and publish our results in an annual report. The report is shared with the Pacific Fishery Management Council and the International Pacific Halibut Commission to help them make management decisions.

The observer program monitors Pacific halibut bycatch in the following fisheries:

- Limited entry bottom trawl.
- Individual fishing quota bottom trawl, hook-and-line, pot, midwater rockfish, and midwater Pacific hake.
- Limited entry sablefish (endorsed and nonendorsed).
- Open access and nearshore fixed gear (hook-and-line and pot).
- The pink shrimp, California halibut, ridgeback prawn, sea cucumber, directed Pacific halibut, and at-sea Pacific hake fisheries.

Definitions of and details on these fisheries can be found throughout this report.

This technical memorandum provides Pacific halibut bycatch estimates for the years 2002 through 2020. Estimates are in metric tons (mt), and are broken out by fishery sector.

Key Takeaways

- On vessels without electronic monitoring, 19.56 mt of halibut were discarded at sea in 2020. This number includes 0.81 mt estimated during the April 2020 two-week COVID-19 waiver period, when these vessels did not carry observers.
- Vessels with electronic monitoring discarded 9.59 mt of halibut in 2020.
- The at-sea Pacific hake fishery discarded 0.39 mt of halibut in 2020, a slight decrease since 2019 (0.54 mt), remaining below the historical average (2002–19: 1.08 mt).
- In the limited entry sablefish endorsed fishery, the amount of discarded halibut in 2020 (8.21 mt) was lower than in 2019 (22.86 mt). This may be due to lower fishing effort or other unmeasured factors.
- No halibut were observed on non-endorsed limited entry sablefish vessels (whether fishing with pot or longline gear).
- Open access hook-and-line vessels discarded 0.34 mt of halibut, a decrease since 2019. No halibut were observed on pot vessels in this fishery.
- Only 3% of vessels in the halibut directed fishery carried observers in 2020, a significant drop since previous years. The observed vessels discarded 11.30 mt of halibut.
- No halibut catch was observed in the California ridgeback prawn fishery.
- Estimated halibut bycatch in most other observed fisheries remained low, and was within the ranges observed in previous years.

Links used in this section:

- Pacific halibut: https://www.fisheries.noaa.gov/species/pacific-halibut
- International Pacific Halibut Commission: https://iphc.int/
- Observer program: https://www.fisheries.noaa.gov/west-coast/science-data/fisheries-observation-science-west-coast
- Direct observation: https://www.fisheries.noaa.gov/topic/fishery-observers
- Electronic monitoring: https://www.fisheries.noaa.gov/west-coast/resources-fishing/electronic-monitoring-west-coast
- Pacific Fishery Management Council: https://www.pcouncil.org/

Acknowledgments

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A note about tables:

Tables 1–7 have been typeset and included in this report. They are also available, together with all the other mentioned tables (8–95), by following the "Supporting Files" link on the report's NOAA Institutional Repository[1] record and downloading the attached Excel file.

[1] https://repository.library.noaa.gov/

Abbreviations

A-S:	at-sea
A-SHOP:	At-Sea Hake Observer Program
DMR:	discard mortality rate
BT:	bottom trawl
EFP:	exempted fishing permit
EM:	electronic monitoring
end.:	endorsed
FG:	fixed gear
H&L:	hook and line
hal.:	halibut
IBQ:	individual bycatch quota
IFQ:	individual fishing quota
IPHC:	International Pacific Halibut Commission
LE:	limited entry
MW:	midwater trawl
non-end.:	nonendorsed
NNSFG:	non-nearshore fixed gear
NS:	nearshore
NWFSC:	Northwest Fisheries Science Center
OA:	open access
P. hal.:	Pacific halibut
PFMC:	Pacific Fishery Management Council
PSMFC:	Pacific States Marine Fishery Commission
sable.:	sablefish
SE:	standard error
TAC:	total allowable catch
TCEY:	total constant exploitation yield
TDM:	total discard mortality
WCGOP:	West Coast Groundfish Observer Program

Executive Summary

Pacific halibut (*Hippoglossus stenolepis,* henceforth P. halibut) is found in coastal waters throughout the North Pacific. Off the West Coast of the United States, it inhabits continental shelf areas (<150 fathoms) from Washington to central California (Clark and Hare 1998, Keith et al. 2014). P. halibut has long supported a directed commercial fishery in the United States and Canada, but it is also caught as bycatch in other fisheries that target demersal species inhabiting similar depths and seafloor habitat types (IPHC and Gustafson 2019).

The objective of this report is to provide estimates of P. halibut bycatch in the U.S. West Coast groundfish fisheries. Bycatch estimates are required for domestic and international management of P. halibut. The International Pacific Halibut Commission (IPHC), a body founded through treaty agreement between the U.S. and Canada, sets the P. halibut annual total constant exploitation yield (TCEY), which is converted to total allowable catch (TAC) for IPHC Area 2A, the collective U.S. marine waters bordering the states of Washington, Oregon, and California. The TAC is based, in part, on bycatch mortality, which takes into account potential survival after being discarded. Regulations for IPHC Area 2A are set by NOAA Fisheries' West Coast Region. Pacific halibut catch in Area 2A is divided between tribal and non-tribal fisheries, between commercial and recreational fisheries, and between recreational fisheries in different states (Washington, Oregon, and California). The Pacific Fishery Management Council (PFMC) describes this P. halibut catch division each year in a catch-sharing plan.

Pacific halibut bycatch in U.S. West Coast groundfish fisheries is estimated from data collected by fisheries observers, from fish sales information, and from review of video imagery from electronic monitoring equipment. The Northwest Fisheries Science Center's (NWFSC) Fisheries Observation Science Program (FOS) has collected discard data from commercial fishing vessels since 2002.[1] Pacific halibut mortality estimates in this report are provided for the years 2002 through 2020 from all fishery sectors observed by FOS (Table 1). This report is updated annually by FOS and presented to PFMC and IPHC for use in P. halibut management.

Table 1. Pacific halibut mortality estimates for 2020 and the years of observation, for all fishery sectors observed by FOS. Estimates include both individuals discarded at the dock and with mortality rates applied, where appropriate. Summarized estimates presented in tables and in the text may exclude small amounts of data to ensure summarized values maintain confidentiality (indicated by asterisks). *TDM* = total discard mortality, *EFP* = exempted fishing permit.

Sector	Years observed	2020 TDM (mt)
Individual Fishing Quota (IFQ) fisheries[a]	2011–20	19.56
IFQ Electronic Monitoring (EM) EFP[b]	2015–20	9.59
At-sea Pacific hake	2002–20	0.39
Non-nearshore fixed gear targeting groundfish	2002–20	8.55
Nearshore fixed gear	2003–20	1.36
Pink shrimp trawl	2004–20	0.00
California halibut trawl	2002–20	0.00
P. halibut directed	2017–20	11.30
Ridgeback Prawn	2017–20	0.00
Sea Cucumber	2017–20	*

[a] Does not include estimates from IFQ vessels with electronic monitoring. Includes all gears.
[b] Includes all gears.

[1] Prior to 2001, at-sea hake fisheries were observed by the Alaska Fisheries Science Center.

In 2020, individual fishing quota (IFQ) fisheries had the largest estimated P. halibut discard mortality of any sector (19.56 metric tons [mt], Tables 1 and 2). The 2020 IFQ fishery estimate of P. halibut discard mortality, coastwide, was 19.56 mt,[2] which includes 0.80 mt estimated during the two-week period in April 2020 when observer coverage was waived for all U.S. West Coast groundfish vessels due to COVID-19 pandemic safety measures (for more details on this waiver period, see Somers et al. 2021a). In 2020, 9.59 mt was caught by IFQ electronic monitoring (EM) exempted fishing permit (EFP) vessels (Table 1 and Supplemental Tables 46, 49, and 52); this amount is included in the IFQ estimate in Table 2 and Supplemental Table 91. The IFQ total (IFQ + IFQ EM EFP = 29.15 mt) is 3.30 mt less than the 2019 estimate (32.45 mt; see Table 2) and, as in past years, well below the individual bycatch quota (IBQ) for P. halibut north of lat 40°10′N allocation (2020 IBQ allocation = 66.34 mt).[3] As in prior years, bottom trawl gear produced the largest component of IFQ discard mortality (IFQ + IFQ EM = 27.22 mt), more than 40% of which was from bottom trawl vessels fishing between Point Chehalis, Washington, and lat 40°10′N (11.97 mt; Supplemental Table 21). The percent of legal-sized P. halibut (>82 cm) discard mortality, by weight (mt), in the IFQ bottom trawl fishery north of lat 40°10′N is presented in Table 3.

For the fourth year, we compare alternative methods for calculating discard mortality rates (DMRs) in the IFQ EM EFP fishery (Supplemental Tables 48 and 51). Electronic monitoring does not yet allow for accurate estimates of P. halibut injuries and viability according to gear type based on IPHC criteria. For in-season P. halibut IBQ management, the Pacific States Marine Fisheries Commission (PSMFC) applies a time-on-deck model (PFMC 2017, Smith 2017) to determine the mortality of individual P. halibut caught on IFQ bottom trawl vessels carrying EM. For final end-of-year reporting in this report, we apply a 0.90 mortality rate to all P. halibut bycatch in the IFQ EM bottom trawl fishery (Supplemental Table 46). As an alternative to the 0.90 rate, we also present mortality estimates based on observer-assessed viabilities and the PFMC Groundfish Management Team's time-on-deck model (see Supplemental Tables 48 and 51). Small sample sizes preclude definitive conclusions from this analysis. FOS may revisit this analysis in future reports.

Table 2 (overleaf). Pacific halibut discard mortality estimates (in mt, including a small amount discarded at the dock in IFQ BT and MW hake fisheries) for all sectors observed by FOS. Mortality rates <1.0 were applied in the BT fisheries (LE and IFQ), IFQ H&L, IFQ pot, and non-IFQ, non-NS FG sectors, for which some information regarding gear-specific survivorship was available. For all other sectors, a 1.0 mortality rate was applied because gear-specific survivorship information is not available. Rounding of values might mask very small weights in some categories, presented here as zero (0). All weights are estimated based on whole fish (a.k.a. round weight, not head-and-gut). IFQ MW rf, ridgeback prawn, and sea cucumber fisheries are not included because either they had zero (0) observed P. halibut catch or the data are confidential. Key: *BT* = bottom trawl, *LE* = limited entry, *H&L* = hook-and-line, *hal*. = halibut, *MW* = midwater, *rf* = rockfish, *sable*. = sablefish, *end*. = endorsed, *OA* = open access, *NS* = nearshore, *A-S* = at-sea, *mort*. = mortality rate, *n/a* = not applicable, * = confidential data (<3 vessels observed), — = no observer coverage.

[2] Summarized estimates presented here and in the tables might exclude small amounts of data to ensure summarized values maintain confidentiality.
[3] IBQ = individual bycatch quota.

Table 2. Pacific halibut discard mortality estimates, 2002–20 (page 1 of 2).

	Total discards (mt), mortality rates not applied															
Year	LE BT 2002–10	IFQ BT[a,b,i]	IFQ H&L	IFQ Pot[i]	IFQ MW hake[b,c,d,i]	LE sable. end.	LE sable. non-end.	OA FG[e]	NS FG[c]	Pink shrimp[c]	CA hal.[c,f]	P. hal. directed	A-S hake[c]	All sectors	All w/ <1.0 mort.[g]	All w/ 1.0 mort.[h]
2002	524.41	n/a	n/a	n/a	n/a	141.76	0.00	—	—	—	0.00	—	1.14	667.31	666.17	1.14
2003	186.65	n/a	n/a	n/a	n/a	197.12	0.17	—	0.00	—	0.00	—	2.65	386.59	383.94	2.65
2004	212.43	n/a	n/a	n/a	n/a	238.54	0.00	—	0.97	0.00	0.70	—	1.13	453.77	451.67	2.10
2005	460.35	n/a	n/a	n/a	n/a	237.90	0.00	—	2.20	0.04	0.03	—	1.97	702.49	698.28	4.21
2006	390.91	n/a	n/a	n/a	n/a	668.62	0.00	—	0.52	—	0.02	—	0.83	1,060.90	1,059.55	1.35
2007	294.38	n/a	n/a	n/a	n/a	132.28	1.73	22.03	0.08	0.21	0.03	—	1.18	451.92	450.45	1.47
2008	305.21	n/a	n/a	n/a	n/a	259.59	2.99	40.51	0.34	0.00	0.31	—	3.98	612.93	608.61	4.32
2009	385.24	n/a	n/a	n/a	n/a	321.60	0.25	35.21	1.28	0.00	0.00	—	0.33	743.91	742.30	1.61
2010	265.08	n/a	n/a	n/a	n/a	137.60	0.39	32.60	0.08	0.00	0.00	—	1.57	437.32	435.67	1.65
2011	n/a	64.25	6.13	3.36	0.35	137.11	21.31	13.13	3.03	0.19	0.00	—	0.61	249.47	245.29	4.18
2012	n/a	67.27	14.79	1.90	0.62	151.25	16.55	23.68	2.24	0.00	0.00	—	0.64	278.94	275.44	3.50
2013	n/a	66.31	3.00	0.99	1.34	22.23	0.01	1.81	1.35	0.00	0.00	—	1.06	98.10	94.35	3.75
2014	n/a	55.95	3.95	0.32	1.36	179.53	0.00	3.64	0.94	0.00	0.00	—	0.37	246.06	243.39	2.67
2015	n/a	69.39	9.81	2.22	0.70	124.32	0.46	10.19	1.43	0.01	0.00	—	0.06	218.59	216.39	2.20
2016	n/a	59.18	6.95	1.78	0.68	178.57	5.22	42.78	3.02	0.00	0.00	—	0.15	298.33	294.48	3.85
2017	n/a	64.84	4.25	1.84	0.51	297.19	0.76	49.95	1.72	0.00	0.00	25.27	0.55	446.88	444.10	2.78
2018	n/a	52.01	4.93	2.64	1.34	226.14	13.79	41.73	1.57	0.01	0.00	15.60	0.66	360.42	356.84	3.58
2019	n/a	53.08	3.56	4.23	*	219.69	80.21	40.11	0.57	0.00	0.00	28.98	0.54	430.97	429.86	1.11
2020	n/a	44.55	n/a	*	*	93.84	0.00	9.64	1.36	0.00	0.00	58.68	0.39	208.46	206.71	1.75

Note: There was no fishing in the IFQ H&L fishery during 2020. The IFQ MW rf (2012–19), ridgeback prawn (2017–20), and sea cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2011 and 2020 IFQ MW rf and the 2018–20 sea cucumber fishery data are confidential.

[a] Starting in 2013, LE CA halibut estimates are combined with IFQ BT estimates.

[b] Includes a small amount landed and discarded at the dock.

[c] 100% mortality rate.

[d] From 2011–14, "shoreside hake."

[e] Starting in 2011, this sector only includes OA CA halibut.

[f] A coastwide discard ratio and coastwide discard estimate could not be computed in the OA FG sector for 2002–06, because WCGOP only covered OA vessels in CA during this time.

[g] LE BT, IFQ BT, IFQ H&L, IFQ pot, LE and OA CA halibut, and non-NS FG.

[h] IFQ MW rf, MW hake, NS FG, pink shrimp, and A-S hake.

[i] Includes P. halibut catch from IFQ EM EFP.

Table 2 (continued). Pacific halibut discard mortality estimates, 2002–20 (page 2 of 2).

	Total mortality (mt), mortality rates applied															
Year	LE BT 2002–10	IFQ BT[a,b,i]	IFQ H&L	IFQ Pot[i]	IFQ MW hake[b,c,d,i]	LE sable. end.	LE sable. non-end.	OA FG[e]	NS FG[c]	Pink shrimp[c]	CA hal.[c,f]	P. hal. directed	A-S hake[c]	All sectors	All w/ <1.0 mort.[g]	All w/ 1.0 mort.[h]
2002	344.82	n/a	n/a	n/a	n/a	22.76	0.00	—	—	—	0.00	—	1.14	368.72	367.58	1.14
2003	124.43	n/a	n/a	n/a	n/a	31.55	0.03	—	0.00	—	0.00	—	2.65	158.66	156.01	2.65
2004	133.12	n/a	n/a	n/a	n/a	38.82	0.00	—	0.97	0.00	0.70	—	1.13	174.74	172.64	2.10
2005	286.52	n/a	n/a	n/a	n/a	38.12	0.00	—	2.20	0.04	0.03	—	1.97	328.88	324.67	4.21
2006	242.47	n/a	n/a	n/a	n/a	107.30	0.00	—	0.52	—	0.02	—	0.83	351.14	349.79	1.35
2007	208.81	n/a	n/a	n/a	n/a	21.24	0.28	3.54	0.08	0.21	0.03	—	1.18	235.37	233.90	1.47
2008	207.81	n/a	n/a	n/a	n/a	41.67	0.48	6.49	0.34	0.00	0.31	—	3.98	261.08	256.76	4.32
2009	251.10	n/a	n/a	n/a	n/a	51.47	0.04	5.64	1.28	0.00	0.00	—	0.33	309.86	308.25	1.61
2010	180.97	n/a	n/a	n/a	n/a	22.12	0.06	5.23	0.08	0.00	0.00	—	1.57	210.03	208.38	1.65
2011	n/a	31.36	0.98	0.89	0.35	11.78	3.06	1.95	3.03	0.19	0.00	—	0.61	54.20	50.02	4.18
2012	n/a	36.21	2.37	0.51	0.62	27.53	0.78	1.51	2.24	0.00	0.00	—	0.64	72.41	68.91	3.50
2013	n/a	32.51	0.48	0.22	1.34	2.85	0.00	0.07	1.35	0.00	0.00	—	1.06	39.88	36.13	3.75
2014	n/a	26.32	0.63	0.08	1.36	28.64	0.00	0.29	0.94	0.00	0.00	—	0.37	58.63	55.96	2.67
2015	n/a	33.41	1.57	0.38	0.70	10.37	0.02	0.40	1.43	0.01	0.00	—	0.06	48.35	46.15	2.20
2016	n/a	33.45	1.11	0.18	0.68	17.15	1.08	2.70	3.02	0.00	0.00	—	0.15	59.52	55.67	3.85
2017	n/a	35.14	0.68	0.78	0.51	42.31	0.03	3.62	1.72	0.00	0.00	2.21	0.55	87.55	84.77	2.78
2018	n/a	30.57	0.79	0.29	1.34	26.30	0.62	4.43	1.57	0.01	0.00	2.48	0.66	69.06	65.48	3.58
2019	n/a	30.03	0.57	0.97	*	23.10	2.81	2.91	0.57	0.00	0.00	3.50	0.54	65.00	63.89	1.11
2020	n/a	27.37	n/a	*	*	8.21	0.00	0.34	1.36	0.00	0.00	11.30	0.39	48.97	47.22	1.75

Note: There was no fishing in the IFQ H&L fishery during 2020. The IFQ MW rf (2012–19), ridgeback prawn (2017–20), and sea cucumber (2017 only) fisheries had zero (0) observed P. halibut catch. The 2011 and 2020 IFQ MW rf and the 2018–20 sea cucumber fishery data are confidential.

[a] Starting in 2013, LE CA halibut estimates are combined with IFQ BT estimates.

[b] Includes a small amount landed and discarded at the dock.

[c] 100% mortality rate.

[d] From 2011–14, "shoreside hake."

[e] Starting in 2011, this sector only includes OA CA halibut.

[f] A coastwide discard ratio and coastwide discard estimate could not be computed in the OA FG sector for 2002–06, because WCGOP only covered OA vessels in CA during this time.

[g] LE BT, IFQ BT, IFQ H&L, IFQ pot, LE and OA CA halibut, and non-NS FG.

[h] IFQ MW rf, MW hake, NS FG, pink shrimp, and A-S hake.

[i] Includes P. halibut catch from IFQ EM EFP.

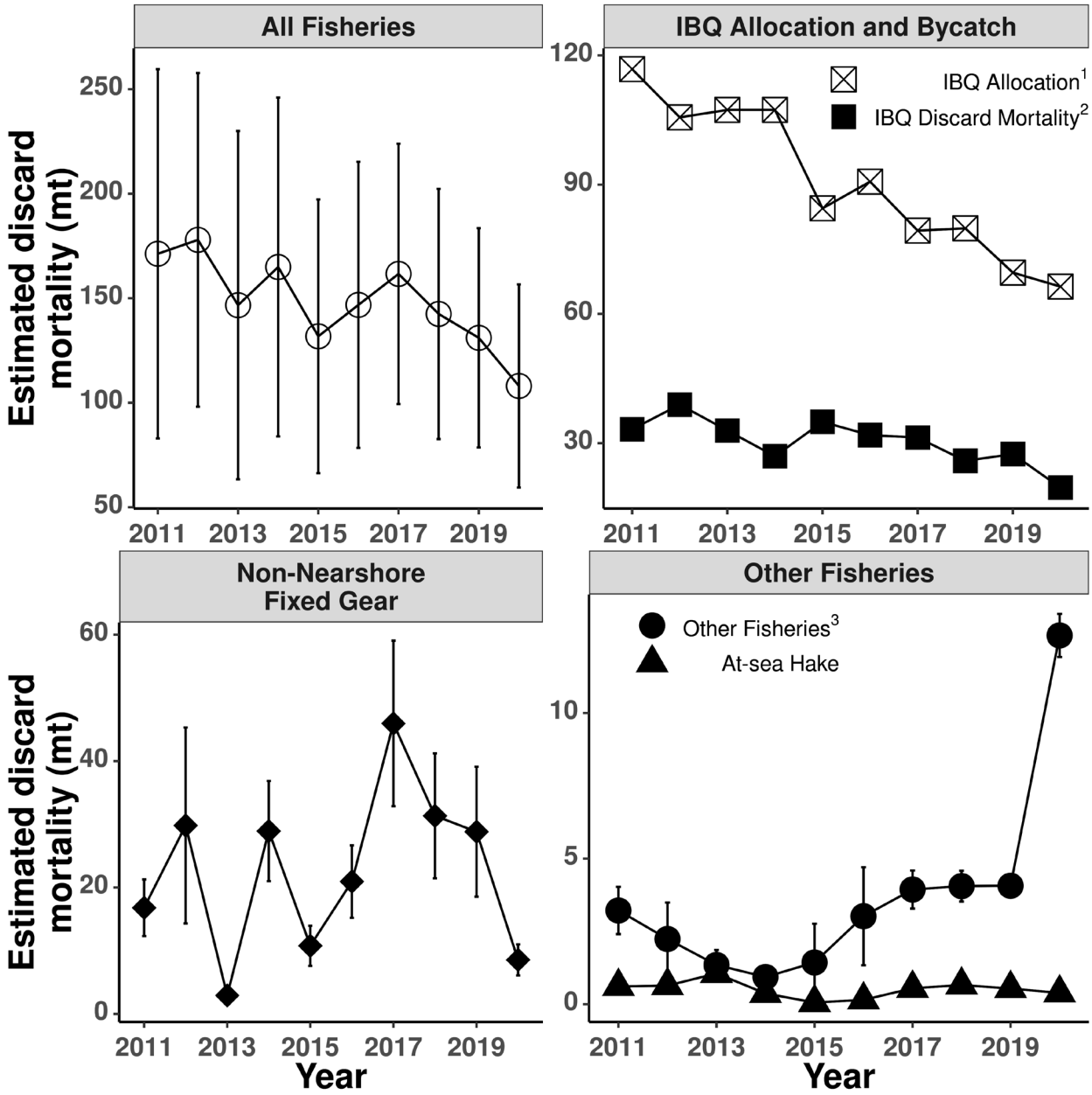

Figure 1. Total estimated P. halibut discard mortality (mt ±1 SE, with mortality rates applied if applicable) from all sectors observed by FOS. Estimates are not included for sectors and years where there were insufficient observer data. Values are reported in Table 2.

[1] IBQ allocated north of lat 40°10′N.

[2] IBQ catch includes all catch share sectors and gears except at-sea hake, which is shown separately.

[3] *Other Fisheries* include OR and CA nearshore, WA, OR, and CA pink shrimp, California halibut, sea cucumber, ridgeback prawn, and IPHC P. halibut directed fisheries.

In 2020, non-nearshore fixed gear vessels targeting groundfish had quite low estimated P. halibut discard mortality compared to previous years (8.55 mt; Tables 1 and 2). Nearly all of that bycatch (7.30 mt, or ~85%) occurred on the limited entry (LE) sablefish endorsed vessels. These vessels fish federally permitted sablefish tier quota during the primary season (April–October). Almost all of the LE sablefish endorsed bycatch occurred while fishing longline gear north of Point Chehalis (6.97 mt or ~96%; Table 66). A smaller amount of P. halibut mortality also occurred on LE sablefish endorsed vessels fishing longline gear south of Point Chehalis (0.34 mt). Limited entry endorsed pot vessels caught 0.91 mt of P. halibut bycatch. Open access (OA) vessels targeting non-nearshore groundfish species with hook-and-line gear caught substantially less (0.34 mt) than the LE sector (0.91 mt). Open access vessels fishing with pot gear and LE non-endorsed vessels fishing either hook-and-line or pot gear did not catch any P. halibut (Table 66).

Table 3. Percent of legal-sized P. halibut (>82 cm) discard mortality, by weight (mt), in the IFQ bottom trawl fishery north of lat 40°10′N.

Year	% legal-sized P. halibut
2011	67.10
2012	66.70
2013	64.00
2014	60.08
2015	67.67
2016	67.23
2017	75.60
2018	79.21
2019	73.50
2020	55.16

The P. halibut discard mortality estimate for the 2020 IPHC directed P. halibut fishery was 11.30 mt (Tables 1 and 2), considerably more than in previous years. This appears to be due to a lower observation rate of these vessels than in the past (Supplemental Table 74), combined with a higher number of P. halibut categorized as seriously injured or dead (Supplemental Tables 76 and 78). Discard mortality estimates were calculated using the same methods as for the non-nearshore hook-and-line fishery, which uses observed estimates of P. halibut viability. Viabilities of observed P. halibut bycatch in the P. halibut directed fishery are given in Supplemental Table 77. Observed lengths of discarded P. halibut in the directed fishery are given in Supplemental Tables 79 and 80.

Pacific halibut discard—in the nearshore fixed gear, pink shrimp trawl, California halibut trawl (combined as *Other Fisheries* in Figure 1), and at-sea Pacific hake pelagic trawl fisheries combined—represents a very small component of total P. halibut mortality (Table 1, Figure 1). There was zero (0) observed catch of P. halibut in the California ridgeback prawn trawl fishery (Supplemental Table 86). Estimates for the 2020 California sea cucumber trawl fishery are confidential and therefore not provided (Supplemental Table 87); however, in the most recent non-confidential year (2017), there was no P. halibut observed in this sector.

Final estimates of discards in observed fishery sectors, including the IFQ EM EFP, are shown in Tables 1 and 2 and Supplemental Table 91. All three tables (and elsewhere in the report) include the small amount of P. halibut landed and subsequently discarded at the dock by IFQ bottom and midwater trawl vessels. The amounts landed and then discarded at the dock are listed by strata in Supplemental Tables 8, 9, and 10. Summaries of P. halibut catch in the IFQ EM EFP are included in Tables 1 and 2 and Supplemental Tables 46, 49, 52, and 91. Summarized estimates presented in both the tables and the text might exclude small amounts of data to ensure summarized values maintain confidentiality.

In addition, we provide historical estimates of P. halibut bycatch in the LE bottom trawl fishery for the 2002–10 period (Table 2 and Supplemental Tables 90 and 91), and P. halibut bycatch estimates for observed, non-IFQ vessels with an EFP targeting groundfish (2002–20, Supplemental Table 88). For completeness, we also include the P. halibut landed catch from Pacific Fisheries Information Network (PacFIN) fish tickets reported by non-groundfish fisheries that are not observed by FOS for the period 2002–20 (Supplemental Table 89).

The FOS data used in this report have been updated to include the most recent data available (2002–20). PacFIN data used in this report were accessed in May 2021. The estimates for all sectors and years (except LE trawl 2002–10) have been recalculated based on these data. For ease of data access and reporting, the majority of tables have been removed from the written report and are provided in the accompanying Microsoft Excel file. In all other respects, this report uses the same methods as last year's report (Jannot et al. 2021).

Introduction

Pacific halibut (*Hippoglossus stenolepis)* is found in coastal waters throughout the North Pacific Ocean. Off the U.S. West Coast, it inhabits continental shelf areas (<150 fathoms [fth]) from Washington to Central California (Clark and Hare 1998, Keith et al. 2014). Pacific halibut has long supported a directed commercial fishery in the United States and Canada, but it is also caught as bycatch in other fisheries that target demersal species inhabiting similar depths and seafloor habitat types (IPHC and Gustafson 2019). The objective of this report is to provide estimates of P. halibut bycatch in the U.S. West Coast groundfish fisheries from 2002–20.

Observed U.S. West Coast Groundfish Fisheries

The U.S. West Coast groundfish fishery is a multi-species fishery that utilizes a variety of gear types. The fishery harvests species designated in the Pacific Coast Groundfish Fishery Management Plan (FMP; PFMC 2019), managed by the Pacific Fishery Management Council (PFMC). Over 90 species are listed in the FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both state (0–5.6 km) and federal (from 5.6 km offshore to the EEZ) waters. Groundfish are both targeted and caught incidentally by trawl nets, hook-and-line gears, and fish pots. Under the FMP, the groundfish fishery consists of four management components:

1. The limited entry (LE) component encompasses all commercial fisheries that require a federal LE permit. The total number of LE permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch (TAC) for commercially desirable species than vessels without an LE permit.
2. The open access (OA) component encompasses commercial fishers who do not hold a federal LE permit. Some states require fishers to carry a state-issued permit for certain OA sectors.
3. The recreational component includes recreational anglers who target or incidentally catch groundfish species. Estimates of P. halibut bycatch in recreational fisheries are compiled by the International Pacific Halibut Commission (IPHC) and are not covered in this report.
4. The tribal component includes native tribal commercial fishers in Washington State who have treaty rights to fish groundfish. Estimates of P. halibut bycatch from tribal fisheries are not included in this report, with the exception of the observed tribal at-sea Pacific hake (a.k.a. Pacific whiting, henceforth referred to as hake) sector, included as part of the at-sea hake values in Table 2 and Supplemental Tables 90 and 91.

These four components can be further subdivided into sectors based on gear type, target species, permit, and other regulatory factors, as shown in Supplemental Tables 92, 93, and 94.

The Fisheries Observation Science Program

NWFSC's Fisheries Observation Science Program (FOS, or the observer program) observes commercial sectors that target or take groundfish as bycatch. The observer program has two components: the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP).

WCGOP was established in May 2001 by NOAA Fisheries (a.k.a. the National Marine Fisheries Service, NMFS) in accordance with the Pacific Coast Groundfish FMP (USOFR 2001). This regulation requires all vessels that catch groundfish in the U.S. EEZ (from 5.6–370 km offshore) to carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-makings and policies have extended NMFS's ability to require vessels fishing in the <5.6-km state territorial zone to carry observers.

A-SHOP moved to NWFSC in 2001. Prior to 2001, observer coverage of the U.S. West Coast at-sea hake fishery was conducted by the North Pacific Groundfish Observer Program; P. halibut samples from that program are available back to the 1970s but are not included in this report. Current (since 2001) A-SHOP program information and documentation on data collection methods can be found in the A-SHOP observer manual (NWFSC 2020a). The at-sea hake fishery has mandatory observer coverage; each vessel over 38 m carries two observers. Beginning in 2011, under individual fishing quota (IFQ) program management, all catcher vessels that deliver catch to motherships are required to carry WCGOP observers or use EM equipment.

The observer program's goal is to improve estimates of total catch and discard by observing groundfish fisheries along the U.S. West Coast. WCGOP and A-SHOP observe distinct sectors of the groundfish fishery. WCGOP observes multiple sectors of the groundfish fishery, including IFQ shoreside delivery of groundfish and hake, at-sea mothership catcher vessels fishing for hake, LE and OA fixed gear, and state-permitted nearshore fixed gear sectors. WCGOP also observes several fisheries that incidentally catch groundfish, including the California halibut trawl and pink shrimp trawl fisheries. A-SHOP observes the fishery that catches and delivers hake at sea, including tribal and non-tribal motherships and catcher–processor vessels.

Pacific Halibut Management and Fishery Interactions

The IPHC, a body founded through treaty agreement between the United States and Canada, sets the P. halibut annual total constant exploitation yield (TCEY), which is converted to TAC for IPHC Area 2A, the collective U.S. waters off the states of Washington, Oregon, and California. The TAC is, in part, based on bycatch mortality, which takes into account potential survival after being discarded. Regulations for IPHC Area 2A are set by NOAA Fisheries' West Coast Region. Pacific halibut catch in Area 2A is divided between tribal and non-tribal fisheries, between commercial and recreational fisheries, and between recreational fisheries in different states (Washington, Oregon, and California). The Pacific Fishery Management Council describes this P. halibut catch division each year in a catch-sharing plan. Outside the P. halibut directed fishery, P. halibut must be discarded at sea, with two exceptions. In some years, including 2020, the LE fixed gear sablefish endorsed

sector is allowed to retain and land incidentally caught P. halibut north of Point Chehalis, Washington, under IPHC regulations. Similarly, under IPHC regulations, the salmon troll fishery in Area 2A can retain and land incidentally caught P. halibut. In addition, the IFQ midwater hake fishery is a maximized-retention fishery. Under this fishery, small amounts of incidental P. halibut take are allowed to be landed and subsequently donated to food banks or destroyed. Other than these two exceptions, small amounts of P. halibut are, on rare occasions, mixed with target species and accidentally landed. These individuals are subsequently donated or destroyed as in the IFQ midwater hake fishery.

In 2011, the LE bottom trawl sector of the U.S. West Coast groundfish fishery began fishing under an IFQ management program. An IFQ is defined as a federal permit under a limited access system to harvest a quantity of fish, representing a portion of the total allowable catch of a fishery that can be received or held for exclusive use by a person (USOFR 2021). The implementation of the IFQ management program in 2011 resulted in changes to P. halibut sampling, including the mandate that vessels must carry NMFS observers on all IFQ fishing trips. A full list of changes to the fishery can be found in Jannot et al. (2012).

Under the IFQ program, P. halibut is managed at the permit level, through individual bycatch quota (IBQ) pounds. An IBQ accounts for bycatch mortality, including any potential survivorship after capture. Currently, this is the only species managed under IBQ for the U.S. West Coast groundfish IFQ fishery. Each federal groundfish permit with a trawl endorsement is allocated IBQ pounds for P. halibut caught north of lat 40°10′N. Pacific halibut caught south of lat 40°10′N are not managed by an IBQ quota, but are reported here under the IFQ fishery.

Data collection and reporting for this fishery are described by gear type in Methods. The shore-based IFQ fishery includes all IFQ fishery components with the exception of at-sea motherships and catcher–processors. Motherships and catcher–processors have a bycatch quota for P. halibut, but it is not accounted for at the permit level.

With the exception of the IFQ fishery, P. halibut bycatch mortality is accounted for at the fishery sector level only. P. halibut is regularly caught as bycatch in the LE sablefish endorsed fixed gear, LE sablefish non-endorsed fixed gear, and OA fixed gear sectors.

Results

Spatial Distribution of Observed Bycatch

Figure 2 portrays the observed P. halibut bycatch along the U.S. West Coast for all fishery sectors and gear types. The majority of observed P. halibut bycatch occurred north of lat 40°10′N, with highest concentrations of bycatch north of Point Chehalis (Figure 2).

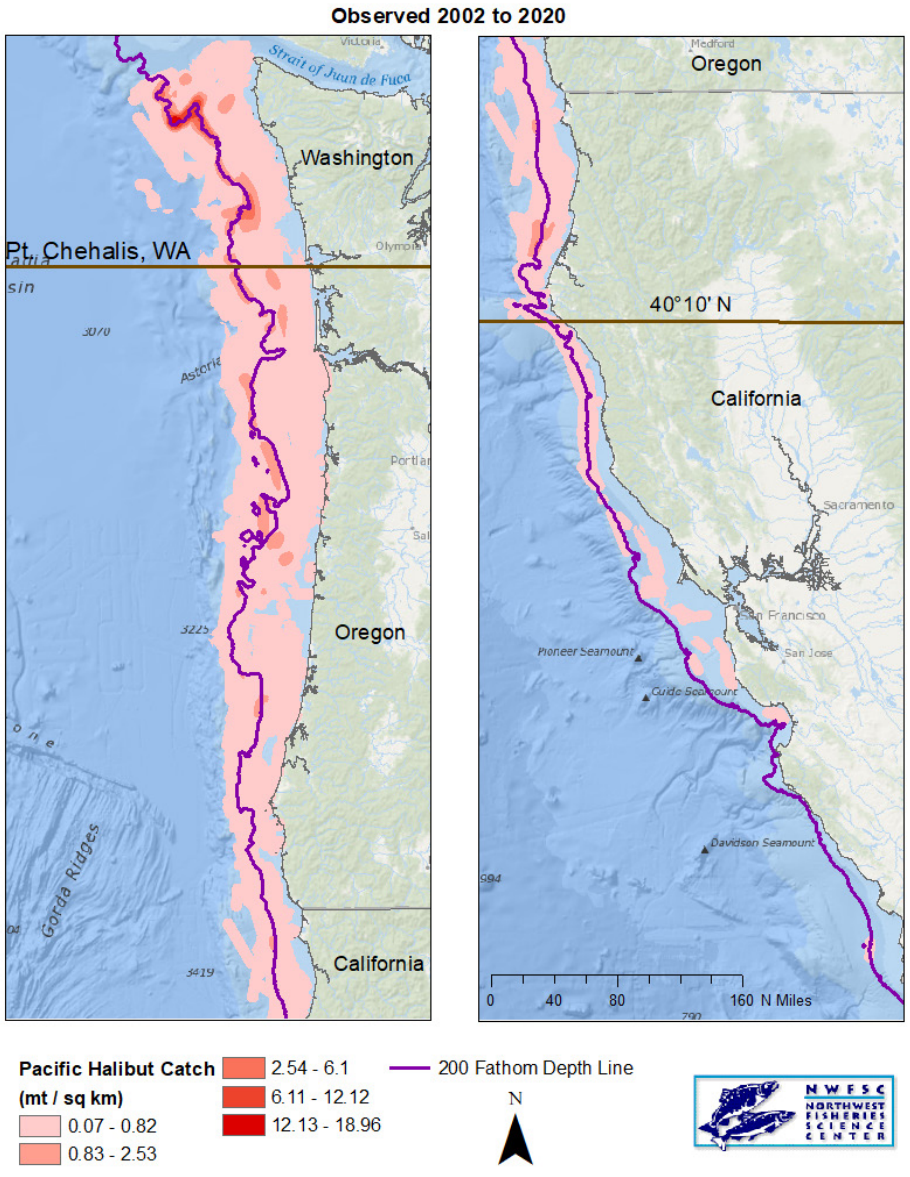

Figure 2. Spatial distribution of P. halibut bycatch (mt/km^2) observed by WCGOP (2002–20) off the U.S. West Coast. Gear types observed include bottom trawl, midwater trawl, shrimp trawl, fixed gear hook-&-line, and pot gear. The five catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted from the map to maintain confidentiality.

IFQ Fishery

All participating vessels carry an observer on all fishing trips under IFQ management (100% trips observed) except those participating in the EM EFP (results discussed separately under IFQ Electronic Monitoring EFP). However, in 2020, to help protect observers and crew from the spread of COVID-19, a two-week waiver period exempting vessels from carrying an observer was instituted during 16–30 April 2020. For this period, we estimated a very small amount of P. halibut discards on IFQ vessels that would normally carry an observer. Only IFQ bottom trawl vessels fished during this two-week waiver period. These vessels caught an estimated total of 1.49 mt of P. halibut which, after applying mortality rates, was an estimated total of 0.81 mt of discarded P. halibut. IFQ vessels using EM continued to use EM as normal, so no alternative estimates were necessary for EM vessels during this period.

Monthly fishing effort by IFQ bottom trawl vessels is shown in Figures 3, 4, and 5. For all 2020 strata, 99% or more of the observed IFQ tows or sets were sampled (Supplemental Tables 8, 9, 10, 11, and 12). IFQ flatfish, IFQ mixed species, and unsorted catch all contributed to unsampled catch (Supplemental Tables 13, 14, 15, and 16; see NWFSC 2020b for IFQ sampling protocols). The total estimated weight of P. halibut from unsampled tows or sets in 2020 represents a small fraction (0.81 mt, or 2.4%) of the total 2020 IFQ gross discard weight of P. halibut (Supplemental Tables 13, 14, 15, and 16).

Gross bycatch estimates and total discard mortality estimates were largest for IFQ vessels fishing bottom trawl gear between Point Chehalis and the lat 40°10′N management line in depths greater than 60 fth (Supplemental Table 21). This gear–area–depth stratum accounts for 55% of the 2020 P. halibut discard mortality in the IFQ fishery (non-EM). The next-largest fraction (27%) of total IFQ discard mortality was caught north of Point Chehalis in the deep stratum (>60 fth). Together, bottom trawl gear fishing north of lat 40°10′N account for ~88% of the 2020 P. halibut discard mortality in the IFQ fishery (Supplemental Table 21).

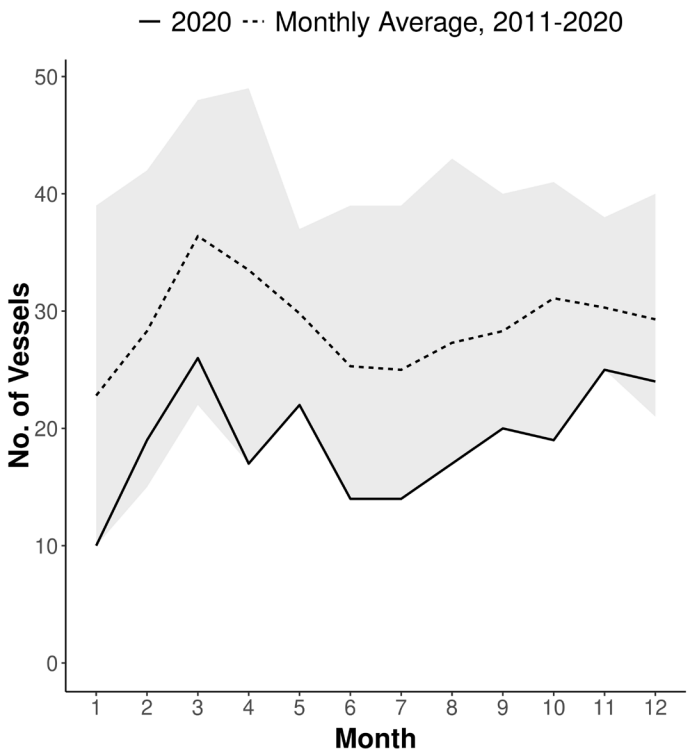

Figure 3. Number of vessels, by month, for IFQ bottom trawl vessels in 2020 (solid line) and averaged over the 2011–20 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–20. Data from vessels using EM are not included.

In terms of viability, the majority of P. halibut on IFQ vessels were classified as either **excellent** or **dead**, depending on the stratum (Supplemental Tables 17, 18, 19, and 20). In 2020, the individuals caught with bottom trawl were split between **excellent** and **dead** condition in the area between Point Chehalis and lat 40°10′N in depths >60 fth. Individuals caught with bottom trawl north of Point Chehalis deeper than 60 fth were more likely to be **dead** than **excellent** (Supplemental Table 17). Gross and discard mortality for bottom trawl vessels, by month, for 2020 are presented in Supplemental Table 29.

Estimated 2020 P. halibut discard mortality from all IFQ sectors and gears is 6.50 mt less than the average for the previous five years (2015–19 mean = 34.54 mt, 2020 = 28.04 mt, including IFQ EM EFP). Gross and discard mortalities for each of the gear types are presented in Supplemental Tables 21–24. Legal-sized (>82 cm) mortality by gear type is presented in Supplemental Tables 25–28. Length frequencies, weighted length frequencies, and percent weighted length frequency information are presented in Supplemental Tables 30–38. Length frequency of dead individuals is displayed in Supplemental Tables 39–41.

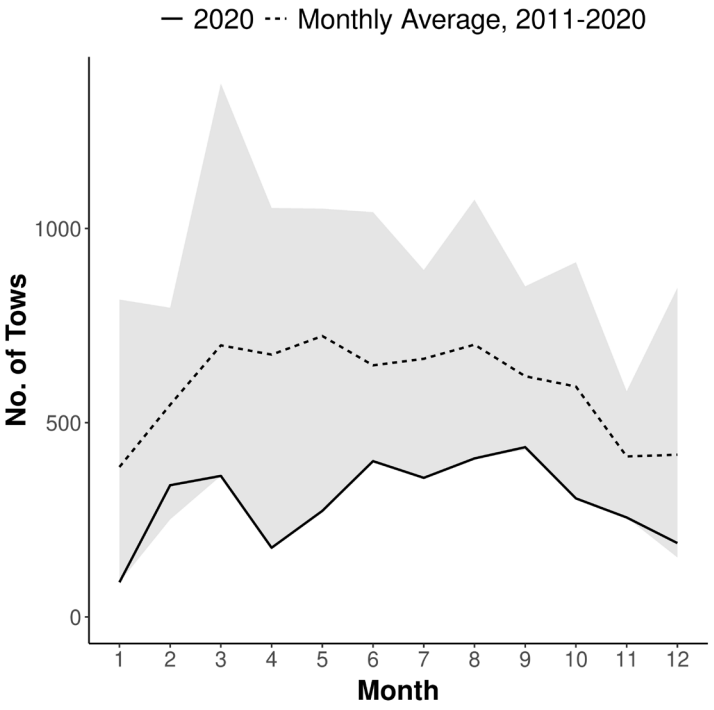

Figure 4. Number of tows, by month, for IFQ bottom trawl vessels in 2020 (solid line) and averaged over the 2011–20 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–20. Data from vessels using EM are not included.

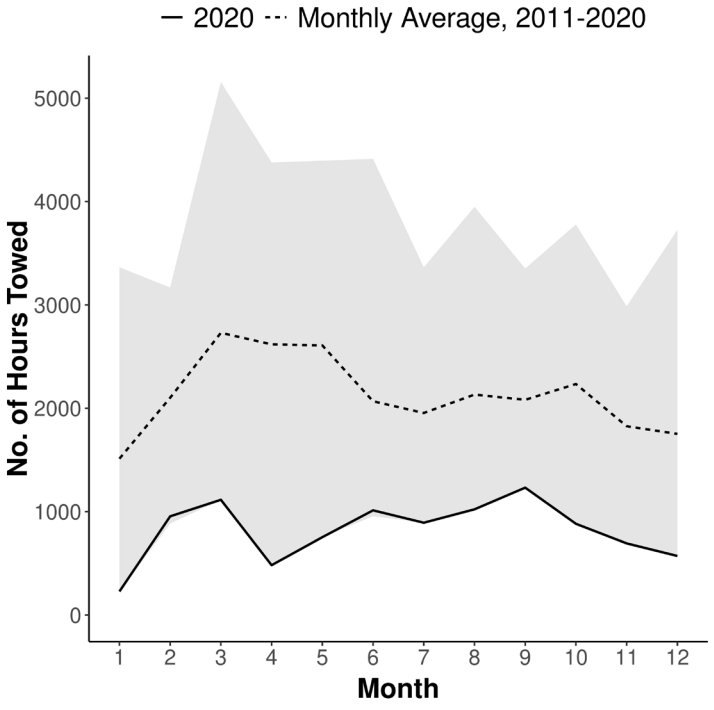

Figure 5. Tow hours by month for IFQ bottom trawl vessels in 2020 (solid line) and averaged over the 2011–20 period (dotted line). Gray ribbon represents the monthly maximum and minimum across 2011–20. Data from vessels using EM are not included.

At-Sea Hake Fishery

Estimated bycatch weight of P. halibut from the at-sea hake component of the 2020 IFQ fishery decreased very slightly from 2019 (2019 = 0.54 mt, 2020 = 0.39 mt; Supplemental Tables 42, 43, and 91). There has been no fishing in the tribal sector since 2012 (Supplemental Table 44). At-sea hake P. halibut length frequencies are given in Supplemental Table 45.

IFQ Electronic Monitoring EFP

Estimated P. halibut discard mortality from the 2020 IFQ EM EFP vessels, including fish discarded at the dock, was 7.65 mt from bottom trawl vessels (Supplemental Table 46), 0.55 mt from pot vessels (Supplemental Table 49), and 0 mt from midwater trawl vessels fishing for rockfish (Supplemental Table 52).

Both IFQ EM bottom trawl and IFQ EM pot vessels had higher DMRs than non-EM IFQ vessels when using the observer viability method (Supplemental Tables 48 and 51). However, the observer viability method on IFQ EM bottom trawl vessels appears to give a lower DMR than the time-on-deck model (Supplemental Table 48). Caution must be used in interpreting these DMRs because sample sizes were very small. The number of EM vessels catching P. halibut was a small subset of the overall EM fleet, and those vessels that did catch P. halibut typically caught very few P. halibut during observer sampling (Supplemental Tables 47 and 50).

Non-Nearshore Fixed Gear Fishery

The 2020 estimated discard mortality of P. halibut in the longline portion of the LE sablefish endorsed sector decreased by 68% from 2019 (2019 = 22.66 mt, 2020 = 7.30 mt; Supplemental Table 66), but is still well within the historical range for this fishery (2.94–104.45 mt; see Figure 6 and Supplemental Table 66). Compared to 2019, the 2020 observed discard ratio decreased both north and south of Point Chehalis (Supplemental Table 58). Estimated discard of P. halibut from the pot portion of the LE sablefish endorsed sector increased compared to 2019 (2019 = 0.46 mt, 2020 = 0.91 mt; Supplemental Table 66). Discard of P. halibut among the LE sablefish non-endorsed longline vessels decreased to zero (0) in 2020. Pacific halibut bycatch in OA hook-and-line decreased during 2020 (2019 = 2.88 mt, 2020 = 0.34 mt; Supplemental Table 66), and pot vessel bycatch decreased to zero (0). Both OA fixed gear sectors still account for only a small portion of total fixed gear bycatch.

Landings of target species decreased for both LE longline and OA hook-and-line vessels in all non-nearshore sectors by roughly between 20% and 30% in 2020 (Supplemental Table 57). Observer coverage was lower than 2019 levels for these vessels (Supplemental Tables 53, 54, and 55), but observed percentages of trips that encountered P. halibut were about the same or lower (Supplemental Tables 59, 60, and 61).

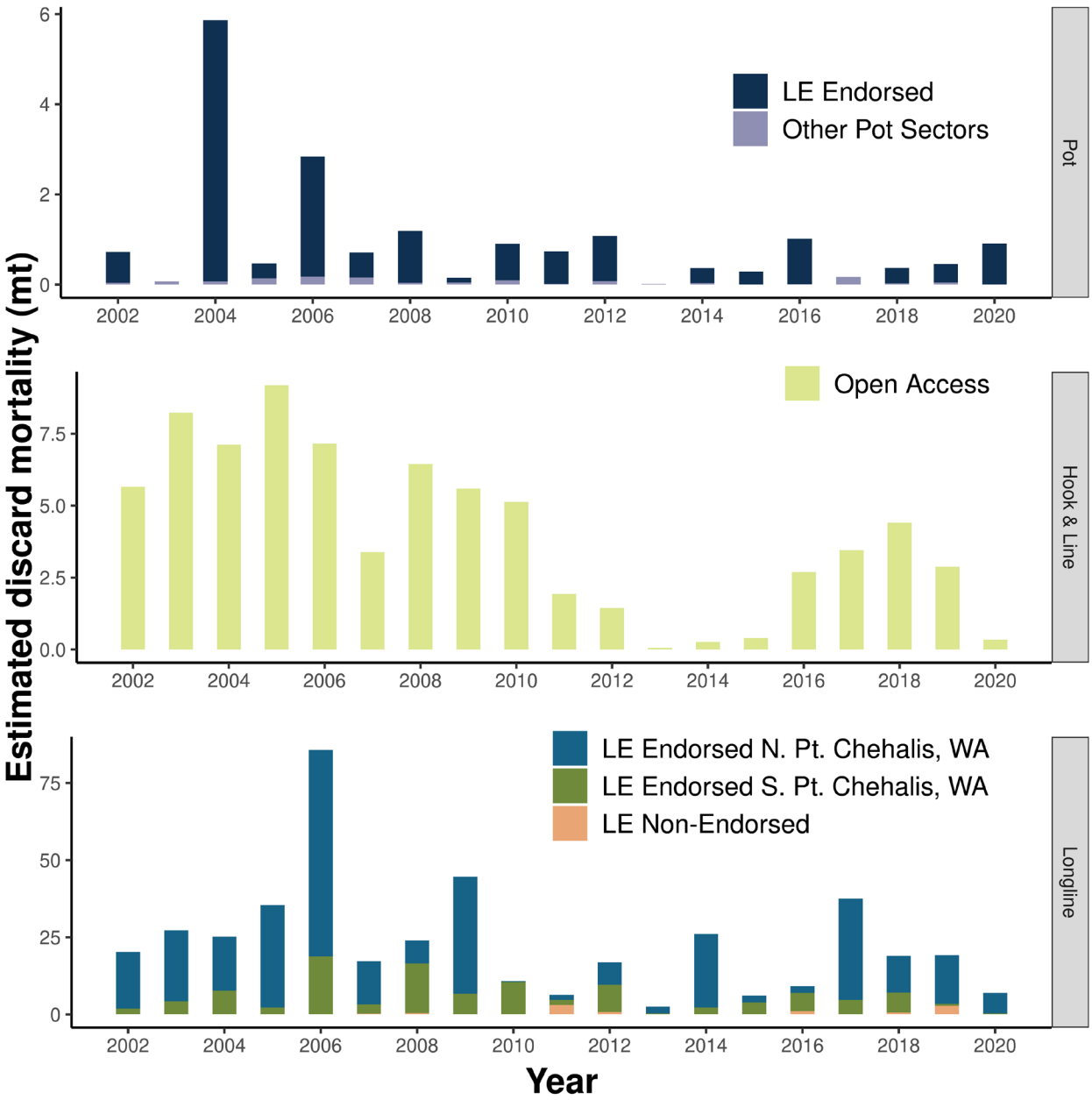

Figure 6. Estimated discard mortality of P. halibut in the non-nearshore fixed gear fishery, by sector and gear for each year. We apply a fixed average discard rate from 2007–08 data to generate 2002–06 discard estimates for the OA sector, because only the California portion of the OA fishery was observed in 2002–06. *Other Pot Sectors* includes LE sablefish non-endorsed and OA fixed gear vessels fishing with pot gear.

Injury assessments on longline or hook-and-line vessels, by year and sector, are presented in Supplemental Tables 62, 63, and 64. Gross discards and discard mortality are presented in Supplemental Tables 65, 66, 90, and 91. Physical measurements of P. halibut length frequencies from the non-nearshore fixed gear sectors can be found in Supplemental Tables 68, 69, 70, and 71. Visual estimates of length frequencies in the non-nearshore fixed gear sectors can be found in Supplemental Table 72. A comparison of the distribution of physical and visual estimates of length frequency is presented in Figure 7.

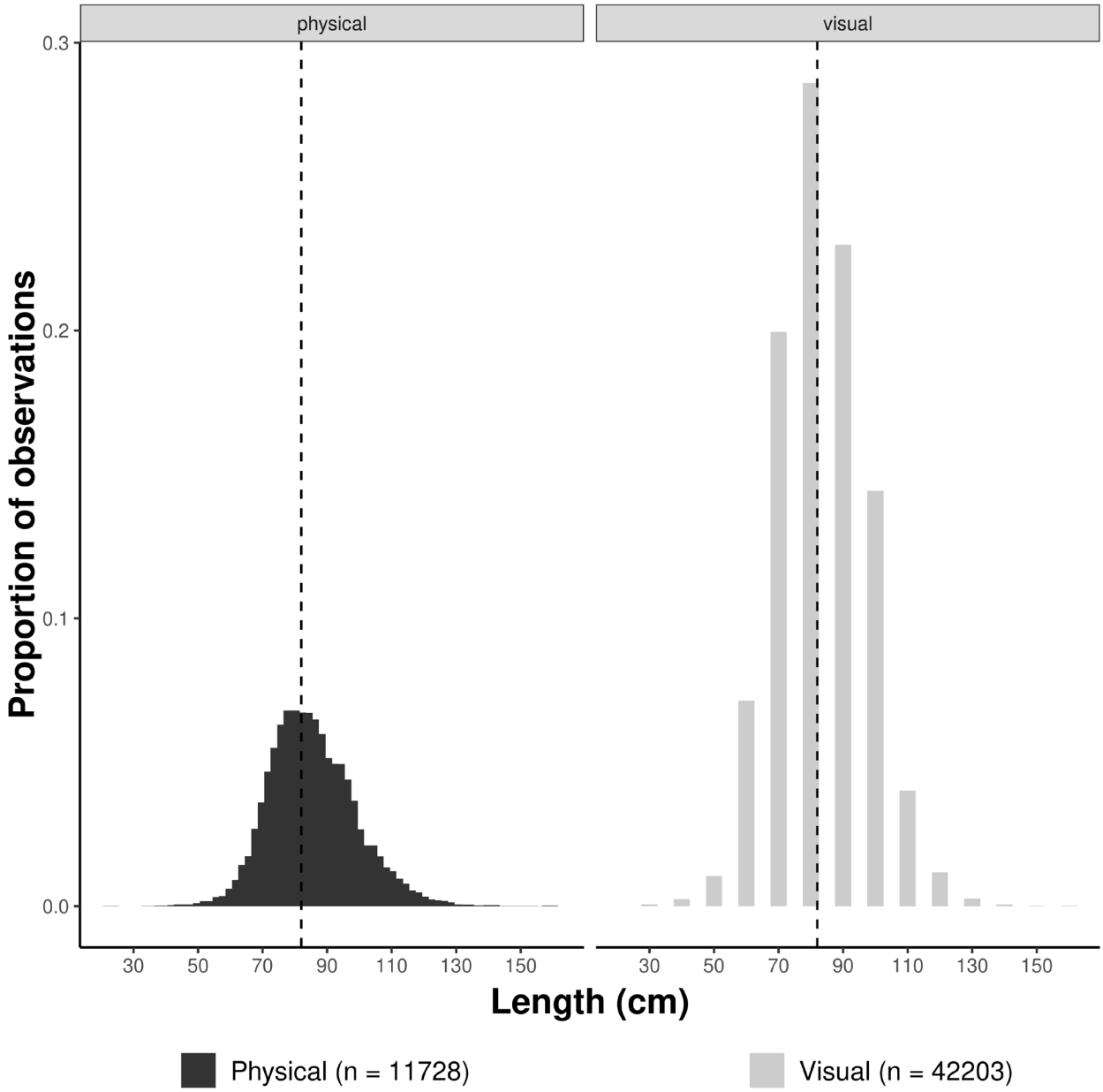

Figure 7. Length frequency distribution of discarded P. halibut on WCGOP-observed non-nearshore fixed gear LE and OA groundfish vessels, Sep 2003–Dec 2020. Visual estimates (gray bars) of P. halibut lengths are only estimated in 10-cm increments. The sublegal–legal size cutoff (82 cm) is indicated by a vertical dashed line.

Legal–Sublegal Length Frequencies

The number and percent of observed P. halibut that were of legal (>82 cm) or sublegal size, by fishery (catch share, non-nearshore fixed gear, at-sea hake) are presented in Supplemental Table 73.

IPHC Pacific Halibut Fishery

The observer program attained a 3% coverage rate (Supplemental Table 74) in the fourth year of covering the IPHC P. halibut directed fishery, a drop from previous years, in part due to COVID-19 safety precautions. In 2020, the first two openings for the fishery were not observed due to COVID-19 restrictions and safety precautions; thus, all observations occurred during the third fishery opener (Figure 8). Exact dates of each opener, by year, are presented in Supplemental Table 75. Observer coverage in this fleet was also influenced by a number of other factors, including space on vessels, observer availability, and needed coverage in other, higher priority, fisheries.

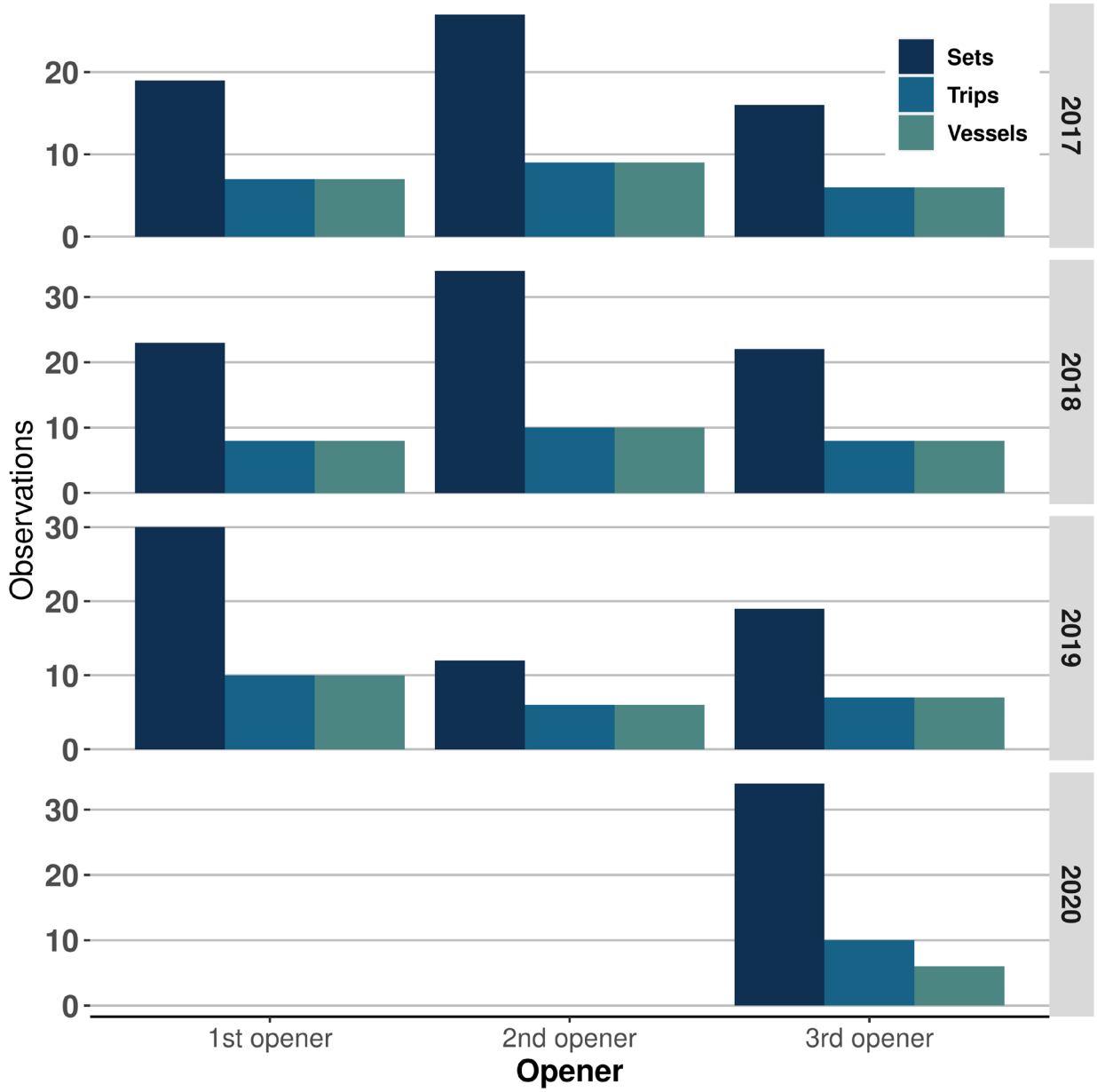

Figure 8. Number of sets, trips, and vessels, by opening day, for the P. halibut directed fishery.

The 2020 P. halibut discard to targeted landings ratio in this fishery was 0.37, leading to a gross discard weight estimate of 58.70 mt (Supplemental Table 76). The majority of discarded fish had minor injuries; however, in 2020, a larger percentage had serious injuries or were assessed as **dead** than in past years (Supplemental Table 77). Thus, the high discard ratio, combined with seriously injured and dead individuals, led to the largest estimated total discard mortality to date, 11.30 mt. The majority of observed P. halibut discards were smaller than legal-size (82 cm), although some were above that size (Supplemental Tables 79 and 80).

Observed State Fisheries, EFPs, and Nongroundfish Fisheries

Very small amounts of P. halibut bycatch were recorded in state-managed observed fisheries. Even assuming 100% mortality, bycatch estimates for the nearshore groundfish fixed gear sector, the pink shrimp trawl fishery, and the OA sector of the California halibut trawl fishery made up a minor portion of the 2020 total mortality estimate for P. halibut (Supplemental Tables 81–85). Zero (0) catch of P. halibut was observed in the California ridgeback prawn fishery (Supplemental Table 86). Data from the 2020 California sea cucumber fishery are confidential (Supplemental Table 87).

Total annual P. halibut bycatch from non-EM EFP vessels has been zero since 2004 (Supplemental Table 88). Pacific halibut landings from non-groundfish fisheries not observed by FOS were 19.04 mt in 2020 (Supplemental Table 89).

Conclusions

IFQ Fishery

- Estimated P. halibut discard mortality in 2020 from IFQ non-EM vessels was 19.56 mt, which includes 0.81 mt estimated during the two-week COVID-19 waiver period. IFQ EM vessels discarded 9.59 mt of P. halibut in 2020. Both non-EM and EM IFQ estimates are similar to previous years.
- EM vessels had very slightly higher discard mortality rates than non-EM IFQ vessels. DMR on EM bottom trawl vessels was lower when using observer viabilities compared to the time-on-deck model; however, sample sizes are still very small, complicating interpretation.
- P. halibut discard from the at-sea hake fishery in 2020 (0.39 mt) showed a slight decrease relative to 2019 (0.54 mt) and remains below the historical average (2002–19: 1.08 mt).[1]

Non-IFQ Fisheries

- The 2020 estimates of P. halibut discard mortality in the LE sablefish endorsed sector (8.21 mt) decreased relative to 2019 (22.86 mt), possibly due to lower effort, but it is not completely clear from available data. The 2020 P. halibut mortality estimates on LE sablefish non-endorsed vessels were zero (0) for both pot and longline gear. Pacific halibut mortality decreased relative to last year on OA fixed gear hook-and-line vessels (0.34 mt), and was zero (0) on OA pot vessels.
- In the IPHC P. halibut directed fishery, observer coverage was down considerably compared to previous years, to 3%. The total P. halibut discard mortality after accounting for viability was 11.30 mt.
- Zero (0) P. halibut catch was observed in the California ridgeback prawn fishery.
- Estimated P. halibut mortality in all other non-IFQ observed fisheries remained low relative to the IFQ and non-nearshore sectors, and was within the ranges observed in previous years.

[1]Prior to 2001, at-sea hake fisheries were observed by the Alaska Fisheries Science Center.

Methods

Data Sources

Data sources for this analysis include on-board observer data (from WCGOP and A-SHOP), landing receipt data (referred to as fish tickets, obtained from PacFIN[2]), and data generated from vessels carrying EM equipment. Currently only vessels in the IFQ sector fishing on an EFP carry EM equipment. EM data are obtained from PSMFC. To date, observer data are the sole source for discard estimation in the IFQ sectors, except for vessels using EM under an EFP, as stated above. All other sectors use a combination of observer and PacFIN data to estimate discard mortality. A list of fisheries, coverage priorities, and data collection methods employed by WCGOP in each observed fishery can be found in the WCGOP manual (NWFSC 2020b). A-SHOP program information, documentation, and data collection methods can be found in the A-SHOP manual (NWFSC 2020a).

The sampling protocol employed by WCGOP is primarily focused on the discarded portion of catch. To ensure that the recorded weights for the retained portion of the observed catch are accurate, haul-level retained catch weights recorded by observers are adjusted based on trip-level fish ticket records. This process is described in further detail on the West Coast Groundfish Observer Program Data Processing web page,[3] and was conducted prior to the analyses presented in this report. All weights of P. halibut presented in this report are round weights, that is, whole fish. IPHC converts these weights to dressed weight (i.e., head and organs removed).

For data processing purposes, species and species groups were defined based on management (see Table A-1 in Somers et al. 2021b). A complete listing of groundfish species is defined in the Pacific Coast Groundfish Fishery Management Plan (PFMC 2019).

Fish ticket landing receipts are completed by fish buyers in each port for each delivery of fish by a vessel. Fish tickets are trip-aggregate sales receipts for market categories that may represent single or multiple species. Fish tickets are issued to fish buyers by a state agency, and must be returned to the agency for processing. Fish ticket and species composition data are submitted by state agencies to the PacFIN regional database. Annual fish ticket landings data were retrieved from the PacFIN database (May 2021) and subsequently divided into various sectors of the groundfish fishery (Somers et al. 2021b).

[2] The Pacific Fisheries Information Network, https://pacfin.psmfc.org/.
[3] https://www.fisheries.noaa.gov/west-coast/fisheries-observers/west-coast-groundfish-observer-program-data-processing

Shore-Based IFQ Fishery

The methods used to report in-season IBQ estimates via the Vessel Account System (VAS) are separate from those methods used to estimate final fleetwide P. halibut mortality. Methods for in-season IBQ estimation are discussed in Jannot et al. 2020. Results obtained by methods described here resulted in fleetwide estimates of P. halibut mortality that are very close to those reported by the VAS.

Pacific halibut data collection in the shore-based IFQ fishery

The WCGOP discard sampling methodologies ensure that P. halibut mortality can be estimated, regardless of the limitations imposed by the vessel, catch composition, or catch quantity. Three pieces of information are necessary to estimate P. halibut mortality (also see Table 4):

1. A count of individual P. halibut in the haul or sample.
2. Actual or visual length measurements (in cm).
3. A viability obtained by physical assessment of individual P. halibut using IPHC-designed dichotomous keys that relate the physical condition of the fish to a viability code (NWFSC 2020b). A unique key is used for each gear type (trawl, longline, pot).

Observers might sample all or a subset of P. halibut caught in a haul/set. The proportion of P. halibut sampled is based on the number of P. halibut caught in the haul/set, the level of assistance provided by the crew, as well as other variables (e.g., physical space, weather). Sampling and assessment of P. halibut depend on crew assistance and cooperation. Regulations prohibit vessel crew from discarding any P. halibut without first notifying the observer. The vessel crew must comply with requests by the observer to ensure proper P. halibut sampling, including but not limited to: modifying P. halibut sorting procedure, assisting the observer by delivering the P. halibut to the observer, and modifying operations to ensure P. halibut sampling is completed. Table 4 describes the P. halibut data obtained on IFQ-permitted vessels fishing different gear types.

On vessels fishing fixed gear (pot or hook-and-line), observers must sample at least 50% of the gear per set. Actual length measurements are obtained on bottom trawl, midwater trawl, and pot vessels, but only visual length estimates are made on vessels fishing hook-and-line gear in the IFQ fishery. Visual estimations use 10-cm increments (55–64 cm, 65–74 cm, etc.).

Table 4. Data collected from P. halibut caught on IFQ vessels using different types of gear.

Gear	Years	Count	Length measurement (cm)	Viability collected?
BT	2011–present	all in the haul	actual, all, or subset	Y
MW[a]	2011–present	all in the sample	actual, all, or subset	Y
Pot	2011–present	all in the sampled portion	actual, all, or subset	Y
H&L	2011–16	all in the sampled portion	visual, all, or subset	N
H&L	2016–present	all in the sample	actual, all, or subset	Y

[a] Midwater trawl only applies to catcher–processor vessels and to catcher-olny vessels delivering to motherships. Catcher-only vessels delivering hake or rockfish shoreside dump hauls directly into the vessel hold, and any P. halibut are delivered to the dock for discard or donation.

The crew's cooperation is vital to the observer's sampling success during hook-and-line fishing. When an observer samples for P. halibut, the crew are not permitted to shake loose or discard any P. halibut before the observer can estimate the fish length, nor can they restrict the observer's view of the line as it comes out of the water. If requested by the observer, the crew is required to physically hand individual fish to the observer, or slow the gear retrieval.

Viability is assessed at the point of fish release when returned to sea. On vessels using "resuscitation boxes" or other techniques to increase the likelihood of survival, condition sampling is performed prior to the fish being returned to sea. Observations of several condition characteristics are used to assign each fish to one of three viability categories for trawl and pot gear: **excellent**, **poor**, or **dead** (Williams and Chen 2004, NWFSC 2020b). Observer field estimates of viability for P. halibut discarded in the IFQ fishery by vessels fishing bottom trawl or pot gear are used to compute the total estimated mortality of discarded P. halibut. IBQ weight (or simply IBQ) refers to the estimated mortality of discarded P. halibut, with the appropriate mortality rate applied based on viability.

Viability categories are used to assign mortality rates to P. halibut. Mortality rates for vessels fishing bottom trawl gear are based on mortality data collected by Hoag (1975), who found some survivorship among fish in the **dead** condition category. Mortality rates for vessels fishing pot gear are based on conservative assumptions of likely survival from pot-induced injuries (Williams and Wilderbuer 1995). Because of the difficulties of collecting P. halibut viability on hook-and-line vessels, we used a DMR of 0.16, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008). Discard mortality was assumed to be 100% for all midwater trawl bycatch estimates.

Table 5. Mortality rates used for each viability category for IFQ BT vessels (Clark et al. 1992).

Sector	Gear	Viability	Mortality rate
Catch share	BT	**excellent**	0.20
Catch share	BT	**poor**	0.55
Catch share	BT	**dead**	0.90

Table 6. Mortality rates used for each viability category for IFQ pot gear vessels. Rates supplied by IPHC.

Sector	Gear	Viability	Mortality rate
Catch share	Pot	**excellent**	0.00
Catch share	Pot	**poor**	1.00
Catch share	Pot	**dead**	1.00

Shore-based IFQ fishery bycatch estimation

We stratified IFQ P. halibut bycatch data based on sector (shoreside non-hake groundfish, shoreside hake, at-sea hake, and LE California halibut) and gear (bottom trawl, midwater trawl, pot, hook-and-line). LE California halibut tows were separated from IFQ bottom trawl tows in 2011–12, but have been combined with IFQ bottom trawl since 2013 because of minimal fishing and to maintain confidentiality. Within the shoreside non-hake groundfish sector, we further stratified using area and depth within each gear type. When confidentiality criteria were met (>2 vessels per stratum), we maintained area and depth strata that were applied to bottom trawl, hook-and-line, and pot gear in previous reports (Heery et al. 2010, Jannot et al. 2011, 2012, 2013) because prior work demonstrated that these variables were correlated with P. halibut bycatch (Heery et al. 2010). Observations from IFQ vessels fishing midwater trawl gear targeting hake or other midwater target species were not post-stratified. In addition to the strata described above, we also provide bycatch estimates north and south of the groundfish management line (lat 40°10′N) for each sector and gear type.

Despite the 100% observer coverage mandate since 2011, there were some rare occasions (e.g., observer illness, trawl net ripped) when tows or sets were only partially or not sampled, or sampled data failed quality control. Data that failed quality control are treated as completely unsampled hauls. In all these cases, we used ratio estimators to apportion unsampled weight to P. halibut, within each stratum. To obtain the estimated weight of P. halibut ($\hat{W}$) when the entire haul or set was unsampled (or data failed), the unsampled discard weight, summed across unsampled hauls within the stratum, was multiplied by the ratio of the weight of P. halibut discard (summed across fully sampled hauls within a stratum) divided by the total discard weight of all species in all fully sampled hauls within a stratum:

$$\widehat{W}_{u,s} = \sum_{u} x_{u,s} \times \frac{\sum w_{f,s}}{\sum x_{f,s}}$$

where, for each stratum:

s = stratum, which includes sector and year and could include, area, depth, and/or gear,
u = unsampled haul,
f = fully sampled haul,
x = weight of discarded catch,
$\hat{W}$ = estimated weight of unsampled P. halibut in the stratum, and
w = sampled weight of P. halibut.

The unsampled weight of partially sampled hauls or sets was categorized into weight of non-IFQ species (NIFQ) or IFQ species. Unsampled IFQ species weight was further categorized into IFQ flatfish (IFQFF), IFQ rockfish (IFQRF), IFQ roundfish (IFQRD), and IFQ mixed species (IFQM). Unsampled P. halibut would only occur in NIFQ (south of lat 40°10′N only), IFQM, or IFQFF unsampled categories. Thus, those are the only categories for which P. halibut is estimated. IFQM included all 2019 IFQ managed species (see USOFR 2011 for a listing of IFQ species). NIFQ included all species encountered that were not designated as an IFQ-managed species. IFQFF included all IFQ flatfish species managed as a complex under the groundfish FMP. North of the lat 40°10′N groundfish management line, P. halibut would be included in unsampled IFQFF or IFQM categories. South of the groundfish management line, P. halibut would only be included in the unsampled NIFQ category.

To obtain the estimated weight of P. halibut ($\hat{W}$) in partially sampled hauls or sets, the unsampled discard weight, summed across partially sampled hauls within the stratum, was multiplied by the ratio of the weight of P. halibut (summed across fully sampled hauls within a stratum) divided by the total discard weight of all species occurring within a category (NIFQ, IFQFF, IFQM) in all fully sampled hauls within a stratum. Estimated P. halibut weight was summed across unsampled categories.

$$\widehat{W}_{p,s} = \sum_{y} \left(\sum_{p} x_{p,y,s} \times \frac{\sum w_{f,s}}{\sum x_{f,y,s}} \right)$$

where, for each stratum:

s = stratum, which includes year and sector, and could include, area, depth, and/or gear,
y = unsampled category (either NIFQ, IFQFF, or IFQM),
p = partially sampled haul,
f = fully sampled haul,
x = weight of discarded catch,
$\hat{W}$ = estimated weight of unsampled P. halibut in the stratum, and
w = sampled weight of P. halibut

Expanded weights of P. halibut obtained using the equations above for unsampled or partially sampled hauls were then added to the sampled weight of P. halibut within each stratum to obtain the total P. halibut weight per stratum.

Viability analysis

We used observer field estimates of viability for P. halibut discarded in the IFQ fishery by vessels fishing bottom or pot gear to compute the total estimated mortality of discarded P. halibut by IFQ gear, sector, and stratum.

To account for the impact of fish size on survivorship, we computed a weighted mortality rate for each condition category. Length measurements associated with each viability record were converted to weight based on the IPHC length–weight table provided in Supplemental Table 95.

A discard mortality rate for each condition category was then computed as the proportion of P. halibut sampled weight in a viability category multiplied by the viability category-specific mortality rate (see Tables 5 and 6):

$$DMR_{csj} = m_c \times P_{csj}$$

where:

c = viability condition (**excellent**, **poor**, or **dead**),
s = stratum, which could include, area, depth, gear, and/or sector,
j = year,
m = mortality rate,
P = proportion of sampled P. halibut weight (w), and
DMR = discard mortality rate.

DMRs for each condition category *c* and stratum *s* were then multiplied by gross discard estimates to compute total estimated discard mortality for each gear type separately:

$$\hat{F}_{sj} = \sum_{c} \left(B_{sj} \times DMR_{sj} \right)$$

where:

s = stratum, which could include, area, depth, gear, and/or sector,
j = year,
c = viability condition (**excellent**, **poor**, or **dead**),
$\hat{F}$ = total estimated discard mortality,
B = gross estimated discard weight, and
DMR = discard mortality rate.

Viability data are collected from only a subsample of the P. halibut that observers encounter. Based on previous evaluations by Wallace and Hastie (2009), we expect that survivorship of P. halibut in bottom trawl tows is most directly affected by the length of the tow and the amount of catch that fills the net. These variables are not part of the bycatch ratio stratification process (above), and their use in stratifying viability data would make it difficult to then apply DMRs to initial gross estimates of bycatch. We found that tow duration was directly related to depth, one of the variables used to stratify discard ratios and initial gross discard estimates for bottom trawl gear. Because depth and tow duration appeared to co-vary, we used depth and area to stratify IFQ viability data collected from bottom trawl gear. For IFQ viability data collected from pot gear, only area is used to stratify the data. For longline gear, we used a discard morality rate of 16%, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008).

Final estimates of P. halibut bycatch and discard mortality are also presented in the context of the estimated mortality of legal-sized halibut. This was computed by applying the proportion of sampled P. halibut weighed in each depth stratum that was legal-sized (82 cm or larger) to initial estimates. Viabilities were then applied to gross legal-sized discard estimates in the same manner as described above.

IFQ Electronic Monitoring DMR Comparison

PFMC staff, the NMFS West Coast Region, and IPHC have requested a comparison of DMRs for bottom trawl and pot vessels in the IFQ program that carry EM equipment versus those that carry observers on 100% of the fishing trips. When notified, EM vessels are required to carry observers for scientific observation, including collection of P. halibut viabilities. WCGOP aims to observe approximately 30% of EM fishing trips. DMRs for EM vessels were calculated and compared using two methods:

1. The observer viability method.
2. The time-on-deck model.

The observer viability method uses human observer data collected on EM vessels. These data are stratified to match, as closely as possible, the current stratification used in the IFQ fishery while meeting confidentiality requirements. Confidentiality of EM data requires combining strata across years, depths, and areas. Mortality data from non-EM IFQ vessels are also shown for comparison purposes. Other than slight modification of stratification to maintain confidentiality, the observer viability method is identical to the method described in Pacific halibut data collection in the shore-based IFQ fishery.

The time-on-deck model was developed in a collaborative process between PSMFC and the PFMC's Groundfish Management Team (GMT). The model measures the time each fish spends out of the water, which correlates with P. halibut viability: the less time a fish spends out of the water, the higher the probability of the fish being in **excellent** viability condition and therefore having a lower estimated mortality rate. The time-on-deck model substitutes for a viability assessment on EM vessels when fisheries observers are not present on the vessel to assess viabilities. The model and discussion are detailed in a PSMFC report to PFMC (Smith 2017), and in a GMT (PFMC 2017).

The comparison is provided for informational purposes only. Due to low sample sizes, FOS cautions against using these estimates for management purposes. Data from 2015–20 were obtained on pot vessels using EM, and from 2016–20 on bottom trawl vessels using EM. The corresponding non-EM data (i.e., 2015–20 pot and 2016–20 bottom trawl) were used to allow direct comparison between vessels with and without EM. Confidentiality in the EM fleet precluded the use of the full stratification currently used in the catch share fishery.

Length frequencies

The length frequency distribution for P. halibut in the 2011–20 IFQ fishery is provided in Supplemental Tables 30–32. Pacific halibut pose unique challenges for observer sampling. Observers typically measure the length of P. halibut and then convert the measurement to weight using the IPHC length–weight conversion table (Supplemental Table 95). Occasionally, observers weigh individual fish. Sometimes crew members presort the catch by removing P. halibut and immediately returning them to sea. Vessel crews presort P. halibut to increase the likelihood of survival of the discarded fish. Presorting is prevalent on vessels fishing with hook-and-line gear. Fishers have raised concerns regarding crew safety when landing large P. halibut. In addition, hook-and-line fishers are concerned that P. halibut individuals would be injured during landing because of their interaction with the vessel "crucifier" (gear used to strip the bait and any catch off of the hook and gangion line). Therefore, shake-offs prior to the crucifier (a form of presorting) are almost universal on IFQ hook-and-line vessels. Another case of presorting can occur when halibut are too heavy and/or awkward to weigh in observer baskets. In all cases of presorting, random samples are not available. Therefore, observers visually estimate the length of the halibut in 10-cm units (40 cm, 50 cm, 60 cm, etc.), which are later converted to weight using the IPHC length–weight conversion table (Supplemental Table 95).

The weighted length frequency distributions of discarded P. halibut for vessels fishing IFQ using bottom trawl or pot gear are provided in Supplemental Tables 34 and 37 and Jannot et al. (2019). Length frequencies have been weighted based on the ratio of total estimated P. halibut discard weight to the weight of P. halibut that was measured in each stratum (see Jannot et al. 2019 for further details). We have summarized the proportion of length measurements in each condition category (**excellent**, **poor**, and **dead**) in Jannot et al. (2019) to inform size-specific modeling of mortality. Within each of these three condition categories, the frequency of sampled fish was weighed in the same manner as length frequency distributions and then summarized for each 2-cm length bin. In addition, we also provide an estimated count of the number of dead individuals in each 2-cm length bin (Jannot et al. 2019). These values were obtained by multiplying the number of individuals in a length bin within a viability category by the condition-specific mortality rate (Tables 5 and 6), or by 1.0 in the case of midwater trawl. We then summed these values across viabilities and rounded to an integer to obtain the number of dead per length bin. This method assumes there is no size-specific mortality.

Non-Nearshore Fixed Gear Fishery

WCGOP samples each non-nearshore fixed gear sector through separate random selection processes, with the LE sablefish endorsed season permits receiving the highest level of coverage, then LE sablefish non-endorsed permits, and OA fixed gear the lowest. LE sablefish endorsed vessels that fish outside of the primary season or that have reached their tier quota in the primary season are not randomly chosen for observation. Given this sampling structure and anticipated differences in variance from one sector to the next, we chose to maintain sector as a stratification variable in our analysis. Testing of alternative stratification schemes (Heery et al. 2010) indicated that latitude and gear type were the most important variables with respect to P. halibut bycatch in the non-nearshore fixed gear groundfish fishery. Bycatch estimates were produced separately for each sector and gear combination. Two latitudinal strata were applied to the LE sablefish endorsed longline sector (north and south of Point Chehalis = lat 46°53′N) because previous modeling demonstrated that these strata significantly improved the fit of predicted bycatch amounts to the amounts observed (Heery et al. 2010). Point Chehalis was used in previous estimates of P. halibut bycatch in the LE sablefish endorsed longline sector because of its relevance to groundfish management and its apparent ability to split out higher bycatch rates off the northern coast of Washington (Heery and Bellman 2009). Evaluations of latitudinal strata for the other fixed gear sectors did not improve the fit of models to an extent that justified their use. Thus, we maintained previous stratifications for the other groundfish fixed gear sectors (Heery and Bellman 2009, Heery et al. 2010, Jannot et al. 2011, 2012, 2013).

Discard estimation

A deterministic approach was used to estimate P. halibut discard for all sectors of the non-nearshore groundfish fixed gear fishery. Discard ratios were computed from observer data as the discarded weight of P. halibut divided by the retained weight (Supplemental Table 57). Retained weight varies by sector in this fishery, and can be either sablefish or all FMP groundfish (except hake—see Supplemental Table 56 for type of retained used; for list of FMP

groundfish species, see PFMC 2019). Ratio denominators were identified for each sector of the non-nearshore fixed gear fishery based on the targeting behavior of that sector. Discard ratios were then multiplied by the total sector landed weight of either sablefish or FMP groundfish (except hake), corresponding to the denominator used to compute the observed discard ratio for each sector. This provided an expanded gross estimate of P. halibut discard for each sector. A DMR (discussed below) was then applied to compute estimated discard mortality.

Total landed weights for each sector are obtained from fish ticket landing receipts. Fish tickets for fixed gear that included recorded weights for sablefish were included in the non-nearshore fixed gear sector. In addition, fixed gear fish tickets without recorded sablefish were included in the non-nearshore fixed gear sector only if groundfish landings were greater than nongroundfish landings on a unique vessel and landing date. Any P. halibut caught on fixed gear fish tickets with a majority of nongroundfish landings are either captured in the estimates from the P. halibut directed fishery (Supplemental Table 78) or nongroundfish fisheries (Supplemental Table 89).

Fish tickets from the non-nearshore fixed gear sector were partitioned into the three commercial fixed-gear sectors (LE sablefish endorsed, LE sablefish nonendorsed, and OA fixed gear) through the following process. Commercial fixed gear fish tickets were first divided out by whether the vessel had a federal groundfish permit (limited entry) or no federal groundfish permit (open access). OA fish tickets were placed in the OA fixed gear groundfish sector. Next, LE fish tickets were separated based on whether the vessel's federal groundfish permit(s) had a sablefish endorsement with tier quota for the primary season or were not endorsed (also referred to as zero-tier). Fish tickets for all LE sablefish vessels with tier endorsements that were operating within this period and within their allotted tier quota were placed in the LE sablefish endorsed sector. If LE sablefish endorsed vessels fished outside of the primary season (season = April to September) or made trips within the season after they had reached their tier quota, the fish tickets were placed in the LE sablefish nonendorsed sector. In addition, fish tickets from nonendorsed LE vessels were also placed in the LE sablefish nonendorsed sector.

Further processing of fish tickets identified and removed the directed commercial P. halibut fishery landings from the non-nearshore fixed gear analysis. The directed P. halibut fishery occurs on specified days each year which are designated by IPHC. LE and OA fixed gear vessels that typically target groundfish can participate in the directed fishery. For most fixed gear vessels (other than LE sablefish endorsed vessels north of Point Chehalis), this is the only time during which they are allowed to land P. halibut. For prior years (2002–19), we identify P. halibut directed fishery fish tickets using definitions supplied by IPHC. For the current year (2020), fish tickets that included P. halibut landings on or within the two days after a directed fishery opening were considered to be part of the directed fishery and not part of the non-nearshore fixed gear fishery targeting federal FMP groundfish. These fish tickets are excluded from the non-nearshore fixed gear analyses. This approach may resulte in the removal of some nondirected fishery landings north of Point Chehalis, but any bias introduced by this step is considered to be extremely small given the short time period across which fish tickets were removed.

WCGOP observer data were stratified according to sector and gear type (longline and pot/trap). As previously described, one additional latitudinal stratum at Point Chehalis (lat 46°53′N) was used for the LE sablefish endorsed longline sector. Some retention of P. halibut was allowed in the LE sablefish endorsed season in the area north of Point Chehalis. The Point Chehalis line was the only latitudinal stratification incorporated into this portion of the analysis, and was only applied to the LE sablefish endorsed sector. Discard amounts provided for the other two gear sectors represent coastwide estimates.

The numbers of observed trips, sets, and vessels are summarized for each sector, gear type, and area, where applicable (Supplemental Tables 53–55). The landed weight of sablefish and FMP groundfish (excluding hake) is used as a measure for expanding discard from observed trips to the entire fleet (Supplemental Tables 56 and 57). Observed discard ratios were calculated by sector, gear type, and area, based on the following equation:

$$\widehat{D}_s = \frac{\sum_t d_s}{\sum_t r_s} \times F_s$$

where:

s = stratum, including gear, sector, gear type, and/or area,
t = observed sets,
d = observed discard (in mt) of P. halibut,
r = observed retained weight (mt) of sablefish or all FMP groundfish except hake,
F = weight (mt) of retained sablefish or all FMP groundfish, excluding hake, recorded on fish tickets in stratum s, and
$\hat{D}$ = discard estimate for stratum s.

For all strata except the LE sablefish nonendorsed longline and the OA sectors, discard ratios were calculated by dividing the stratum discard weight of P. halibut by the retained catch weight of sablefish. Retained groundfish was used as the ratio denominator for the LE sablefish nonendorsed longline and the OA sectors, because they target a wider range of groundfish species. A broader denominator was therefore necessary to effectively capture the level of fishing effort in these sectors.

Where FMP groundfish (excluding hake) was used to compute discard ratios, retained weights recorded by the observer not appearing on fish tickets were excluded from the denominator. This prevents double-counting associated with differences in the species codes used by observers and processors. For instance, while observers may record rockfish catch at the species level, various species of rockfish are often grouped, weighed, and recorded together on the fish ticket by the processor under a grouped market category (e.g., “northern unspecified scope rockfish”). In some cases, this difference in species coding prevents observer and fish ticket weights from being matched and adjusted properly. Species coding on fish tickets varies considerably between processors and over time, and it is not possible to make assumptions regarding which individual observer-recorded species likely coincide with species grouping codes on fish tickets. By using only the retained groundfish weight from fish tickets in discard ratio denominators, we prevent double-counting of retained weights. This is not a factor when using a single species, such as sablefish, in the denominator, as any retained weights in observer and fish ticket data that share the same species code will match and adjust properly.

The expansion factors for each fishery sector and gear type can be found in Supplemental Table 57. The discard rate multiplied by the expansion factor yielded an expanded gross P. halibut discard estimate for each stratum (Supplemental Table 65). If landings were made by a fixed gear sector for which there were zero or very few WCGOP observations, the most appropriate observed discard ratio was selected and applied to those landings based on similarities in the fishery management structure, fishing and discard behavior, and the gear fished. LE sablefish endorsed vessels that fish outside of the primary season with pot gear often land a small amount of groundfish; however, this portion of the fleet is not observed by WCGOP. Given similarities in gear type and catch composition, OA fixed gear pot observations were selected as the most appropriate source of information for an observed discard rate (Supplemental Table 56).

Discard mortality rates

Once an initial gross P. halibut discard weight was estimated, this value was multiplied by a discard mortality rate (Table 7) to generate final discard mortality estimates (Supplemental Tables 66 and 67, Figure 6). Discard mortality is approximated based on viabilities in a manner similar to the approach used for IFQ bottom trawl. Observers have systematically collected viability data on hook-and-line vessels in the non-nearshore fixed gear sector since 2011. Current methods require observers to collect a length and viability on the first five P. halibut observed in each set on these vessels and to ignore any injuries incurred during landing when assessing viability. For the period 2002–10, we used a single mortality rate for all bycatch (16%) on longline and hook-and-line vessels, which represents an average of DMRs over all years for the Bering Sea/Aleutian region longline fishery (Williams 2008). For the period 2011–20, we used observer field estimates of discarded P. halibut viability on non-nearshore fixed gear vessels fishing longline or hook-and-line gear to estimate mortality of discarded P. halibut. (*Note*: Observers currently do not take viability of P. halibut caught on IFQ hook-and-line vessels).

Methods used to calculate discard mortality based on viability condition are almost identical to those methods currently accepted for use with IFQ bottom trawl vessels (see Shore-based IFQ fishery bycatch estimation). To account for the impact of fish size on survivorship, we computed an annual weighted mortality rate for P. halibut in each condition category in the LE sablefish endorsed fishery (Supplemental Table 62). For the LE Sablefish nonendorsed and OA fixed gear sectors, sample sizes were too small to calculate an annual rate. Therefore, we calculated a five year running average of weighted mortality rates for each condition category in these two sectors (Supplemental Tables 63 and 64). Length measurements associated with each viability record were converted to weight based on the IPHC length–weight table provided in Supplemental Table 95.

Table 7. Mortality rates used for each of the injury categories for non-nearshore hook-and-line vessels (Trumble et al. 2000).

Sector	Gear	Injury status	Mortality rate
Non-nearshore fixed gear	H&L	minor	0.04
Non-nearshore fixed gear	H&L	moderate	0.36
Non-nearshore fixed gear	H&L	severe	0.66
Non-nearshore fixed gear	H&L	dead	1.00

The proportion of P. halibut sampled weight in a viability category was multiplied by the viability category-specific mortality rate (Table 7). DMRs for each condition category *c* and stratum *s* were then multiplied by gross discard estimates to compute total estimated discard mortality for each subsector separately.

Viabilities from pot gear would be appropriate to use in estimating discard mortality; however, bycatch of P. halibut in pot gear is infrequent and the sample size is too small to utilize in this analysis. Consistent with past reports, we relied on DMR computed for Alaska groundfish fisheries (Williams 2008). An 18% DMR was applied to estimates for pot gear, coinciding with the DMR used for the sablefish pot fishery in Alaska.

For additional context, we present the length frequency distribution of P. halibut from visual length estimates and physically measured lengths in non-nearshore fixed gear sectors (Supplemental Tables 68–72) and the proportion of sampled P. halibut discard of legal (>82 cm) and sublegal (<82 cm) sizes in non-nearshore fixed gear sectors (Supplemental Table 73). The majority of P. halibut lengths recorded in these fisheries were visual estimates of length, rounded to the nearest 10 cm. In other words, specimens that are 76 cm and 82 cm are both visually estimated to be 80 cm. With this level of resolution, it was not possible to compute the exact proportion of sublegal versus legal P. halibut from visually estimated lengths. Visual estimates were instead summarized in the manner in which they were recorded, with both sublegal- and legal-sized P. halibut falling within the 75–84-cm length bin.

IPHC Pacific Halibut Directed Fishery

In 2017, WCGOP began observing the P. halibut directed fishery and estimating fleetwide discard mortality using WCGOP observer and fish ticket data. This fishery was defined based on using fixed gear and landing P. halibut within two days of the halibut directed openings (Somers et al. 2021b). Prior to 2017, landings in this fishery were identified using criteria from IPHC and reported in the nongroundfish fisheries not observed by NWFSC in previous versions of this report. No estimates of discards were calculated prior to 2017. Effort in this fishery occurs primarily in Washington and Oregon and uses only hook-and-line gear. Gross discard and mortality estimates for P. halibut were computed based on the same methods as described above for the non-nearshore hook-and-line fisheries. However, for the P. halibut directed fishery, we used P. halibut as the retained weight for both discard rates and expansion factors. We estimated landings, discard, and total mortality in the P. halibut directed fishery (Supplemental Tables 74, 76, and 78). Because the gear and effort in this fishery are similar to the non-nearshore hook-and-line fisheries, the same mortality rates based on viability (Table 7) were applied to discarded P. halibut in the directed fishery (Supplemental Table 77). We also present the number of observed vessels, trips, and sets for each opening of the fishery (Figure 8) and the observed physical and visual length frequencies of discarded P. halibut (Supplemental Tables 79 and 80).

Observed State Fisheries

If present, P. halibut bycatch was also sampled in the following state-managed fisheries:

- Oregon and California nearshore groundfish fixed gear sectors (Supplemental Tables 81 and 82).
- Washington, Oregon, and California pink shrimp trawl fisheries (Supplemental Tables 83 and 84).
- OA California halibut trawl fishery (Supplemental Table 85).
- California ridgeback prawn trawl fishery (Supplemental Table 86).
- California sea cucumber trawl fishery (Supplemental Table 87).

Note that the LE California halibut fishery is covered under the IFQ fishery. Bycatch estimates for these fishery sectors were computed within each fishery based on the following equation:

$$\hat{B} = \frac{\sum_t b}{\sum_t r} \times F$$

where:

t = observed sets/hauls,
b = observed discard (in mt) of P. halibut on set/haul t,
r = observed retained weight (mt) of target species on set/haul t,
F = weight (mt) of retained target species in the fishery in question in a particular year, and
$\hat{B}$ = discard estimate of P. halibut (mt) in the fishery in question in a particular year.

The nearshore fixed gear fishery targets a variety of groundfish and state-managed nearshore species that inhabit areas less than 50 fth deep. All species included in the nearshore target group, as listed on the WCGOP data processing web page, were included in the denominator when calculating bycatch ratios for the nearshore fixed gear sector. Pink shrimp and California halibut were considered the target species in their respective fisheries. Discard mortality rates are not available for California halibut and pink shrimp fisheries due to a lack of information regarding survivorship. To maintain confidentiality, the nearshore fisheries cannot be split out by gear type (hook-and-line vs. pot). For these reasons, we assumed 100% mortality in the nearshore, pink shrimp, and California halibut fisheries.

In 2017, WCGOP began placing observers on California sea cucumber trawl and California ridgeback prawn trawl vessels. Prior to 2017, landings in these fisheries were included in nongroundfish fisheries not observed by NWFSC, and no estimates of discards were calculated. Effort in these fisheries occurs only in California, uses shrimp and bottom trawl gears, and targets sea cucumbers or ridgeback prawns. Discard estimates for each species were computed based on the same equation as described above for the OA California halibut fishery, but utilizing sea cucumber or ridgeback prawn as the retained weight for both discard rates and expansion factors. We assume 100% mortality. In 2017, there was no observed catch of P. halibut in the CA sea cucumber trawl fishery (Supplemental Table 86). Confidentiality protections prevent reporting of the 2018–20 California sea cucumber trawl fishery P. halibut bycatch (Supplemental Table 87).

Exempted Fishing Permits

EFPs are federal permits issued by NMFS authorizing vessels to engage in fishing operations that otherwise would be prohibited by regulation (PFMC Council Operating Procedure 19).[4] EFPs directed toward groundfish species have been required to carry WCGOP observers on 100% of trips. Thus, to obtain the catch from EFPs, we sum the at-sea discards and landed P. halibut catch.

Since 2015, vessels in the IFQ fishery could elect to participate in an EM EFP. To obtain the catch from the IFQ EM EFP, we sum the P. halibut catch from the EM data supplied to FOS by PSMFC. Unlike the normal IFQ program, IFQ vessels fishing under an EM EFP are not required to carry an observer on every fishing trip, because EM is used to ensure compliance with the IFQ program. FOS targets 30% of randomly selected IFQ EM trips for observer coverage for the purposes of scientific observation (e.g., biological sampling). A comparison of the discard mortality rates between the EM and non-EM IFQ vessels and between the observer viability method versus the time-on-deck model are presented in Supplemental Tables 48 and 51.

Nongroundfish Fisheries Not Observed by NWFSC

Nongroundfish fisheries that are not observed by FOS occasionally record P. halibut catch on fish tickets. Data from these fisheries are only available to FOS from PacFIN fish ticket records. We provide a summary of landed P. halibut from these fisheries by year in Supplemental Table 89.

[4] https://www.pcouncil.org/documents/2019/10/agenda-item-h-5-attachment-1-council-operating-procedure-19-protocol-for-consideration-of-exempted-fishing-permits-for-groundfish-fisheries-electronic-only.pdf/

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